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The Pathogenicity of *Fusarium niveum* (EFS.) and the Development of Wilt Resistant Strains of *Citrullus vulgaris* (Schrad.)

By D. R. Porter and I. E. Melhus

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
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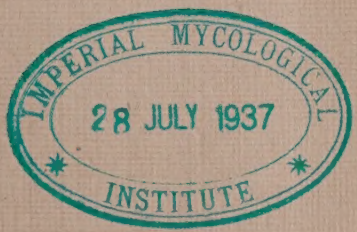
C. F. Curtiss, Director

BOTANY AND PLANT PATHOLOGY SECTION



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SUMMARY

Watermelon wilt, caused by *Fusarium niveum* EFS., is a serious disease in Iowa as well as in many other sections of the United States. The present Iowa acreage is 90 percent less than it was before wilt became a factor.

Infection may occur through the roots formed on a runner covered with infested soil. Injury induced by wind-blown sand seemed to favor wilt infection.

Comparative physiologic tests were made with 18 cultures of *Fusarium niveum* obtained from widely separated localities. These cultures seemed to differ in: (a) rate of growth on artificial media, (b) type of pigmentation, (c) rate of starch digestion, (d) ability to change the pH of neutral media, (e) gross growth habit and (f) degree of sporulation.

Seedling rot is more severe at a soil temperature of 16-18° C. than at 22-25° C. or 25-28° C. According to laboratory trials seedling rot may be partially prevented by treating the seed with certain organic mercury dust fungicides.

Seedling wilt is more severe at a soil temperature of 25-28° C. than at a lower temperature. Relative resistance of the varieties Kleckley Sweet and Stock Citron remains unchanged when seedlings are transplanted from steamed soil into infested soil.

The correlation between rate of wilting and degree of soil infestation appears to be positive. This applies whether or not the soil is naturally or artificially infested and whether or not seeds are planted in infested soil or seedlings are transplanted from steamed soil into infested soil.

There is a tendency toward positive correlation of the rate of wilting in the field and the air temperature. In general, rapid wilting is accompanied by warm weather.

The application of lime, manure and commercial fertilizer in various proportions to infested field soil failed to reduce infection of the variety Kleckley Sweet.

Resistance to watermelon wilt among the varieties of *Citrullus vulgaris* is relative. In general, the edible varieties are susceptible, while the inedible varieties are resistant.

Slight differences in the relative resistance of edible varieties exist, the variety designated as "Japan No. 7" being the most resistant of the edible varieties tested. The variety Conqueror, under Iowa conditions, is only slightly more resistant than Kleckley Sweet.

Marked differences in the relative resistance of inedible varieties exist, the variety Preserving Citron being the least

resistant, and the varieties White Seeded and Majorta being the most resistant of the varieties tested.

A genotype was isolated from the variety Kleckley Sweet, a commercial type, whose progeny was approximately 50 percent resistant in 1928, while Kleckley Sweet was 100 percent susceptible. This selection is designated, temporarily, as K-S4. (Later K-S4 was distributed as the variety Pride of Muscatine).

Five hybrids resulting from crosses of the variety Conqueror on the commercial varieties Kleckley Sweet, Tom Watson, Halbert Honey and Excel were more resistant than these varieties in 1928 and 1929. The relative resistance of these hybrids in 1928 was as follows: hybrid 30, 46 percent; 33, 59 percent; 43, 22 percent; 90, 35 percent and 137, 55 percent. The check variety Kleckley Sweet was 99 percent susceptible.

Two hybrids, Q21 and Q23, apparently chance crosses with the variety Conqueror as one parent, were 68 and 64 percent resistant in 1928, when, under similar conditions, the varieties Kleckley Sweet, Tom Watson, Thurmond Grey, Excel, Dixie Belle and Halbert Honey were 99 percent susceptible. (Later Q21 and Q23 were distributed as varieties Iowa Belle and Iowa King, respectively).

F_2 hybrids of the variety Preserving Citron on Tom Watson were resistant to wilt, but highly susceptible to mosaic.

F_3 hybrids resulting from crosses of the variety White Seeded on the variety Halbert Honey were resistant in 1927 and 1928. Type and flesh quality of the melons varied. The F_3 of this cross produced 26.8 percent of red-fleshed melons. One family, namely 156-S2-S3, produced 44.2 percent red-fleshed melons.

Technique is described for measuring the relative resistance of varieties, selections and hybrids in the seedlng stage grown in the greenhouse.

The Pathogenicity of *Fusarium niveum* (EFS.) and the Development of Wilt Resistant Strains of *Citrullus vulgaris* (Schrad.)

By D. R. Porter and I. E. Melhus

Watermelon wilt (*Fusarium niveum* EFS.) has gradually spread until it has become a serious limiting factor in watermelon production in every melon growing district in the United States. It has been reported from all the states where watermelons are grown extensively and in certain states has caused annual losses as high as 90 percent of the crop. In Iowa it has reduced the average annual acreage 90 percent and the average annual shipments from about 3,000 to less than 50 carloads.

The excellent work of Erwin F. Smith (32, 35) in establishing the cause of watermelon wilt, and the early work of Orton (17) demonstrating, (a) the existence of varietal resistance, and (b) the possibility of developing resistant strains, were a great impetus to the investigation of the cause and control of plant diseases induced by species of the genus Fusarium. Following Orton's (19) lead, work was begun in 1926 in an effort to develop a resistant variety suitable for Iowa growers.

In order to carry on this work it soon became evident that further investigation of symptoms, infection, environmental influences, pathogenicity and seedling resistance was necessary to make maximum progress in the control of this disease. It is the purpose of this paper to present the results of studies of the biology and host relationships of *Fusarium niveum,* and of attempts to develop varieties, selections and hybrids resistant to watermelon wilt.

REVIEW OF PERTINENT LITERATURE

In 1894 Smith (32) proved the pathogenicity of the organism causing watermelon wilt and named it *Fusarium niveum.* He found that: (a) It was a vascular parasite which entered the plant through the infested soil, (b) it interfered with the movement of water through the plant, (c) it produced microconidia in abundance within the tissues of infected plants, and (d) infection took place during the first few weeks after the seed was planted. The following year, Smith (33) identified macroconidia and chlamydospores and reported that the fungus lived over

winter in the soil, and when the fungus was grown on artificial media containing high starch content free from alkali, various brilliant colors such as yellow, brown, crimson and purple appeared. In 1897 he (34) reported that the organism was often disseminated with manure. This research was followed in 1899 (35) by an excellent report of the morphology, vitality, longevity, pathogenicity and dissemination of the fungus. He described some of the symptoms on seedlings and more mature plants, gave an account of the relation of the fungus to the host and stated that watermelon wilt was caused by *Neocosmospora vasinfecta* var. *nivea,* the perfect stage of the causal organism. He was unable, however, to produce either (a) infection with ascospores of Neocosmospora, or (b) the perfect stage of Neocosmospora in culture from asexual spores of *F. niveum.*

Higgins (7) was unable to confirm Smith, when he showed that *Neocosmospora vasinfecta* did not produce macroconidia, chlamydospores, pigmentation on artificial media, nor perithecia from conidia of *Fusarium vasinfectum.* Butler (1), working in India, proved that *N. vasinfecta* was a common saprophyte, fruiting on plant tissue which had been killed by other organisms. He did not get conclusive cases of wilt when he inoculated pigeon-pea, cotton, or indigo with subcultures from ascospores of *N. vasinfecta.* Higgins (7), however, worked with *F. vasinfectum* Atk., while Butler (1) worked with *Fusarium udum* Butler.

It remained for Wollenweber (42) to demonstrate that watermelon wilt was not caused by *Neocosmospora vasinfecta* and that there was no genetic connection between *N. vasinfecta* and *Fusarium niveum.* He found that mycelium, microconidia and macroconidia of *N. vasinfecta* were unable to produce wilt. Moreover, he found that Neocosmospora had no sporodochial or pionnotes stage, that macroconidia were seldom produced and that chlamydospores were lacking. He found also slight differences in the morphology of the septate asexual spores of the two organisms. Because of morphological and physiological differences in the two organisms and because *N. vasinfecta* was unable to produce symptoms of wilt, Wollenweber confirmed the report of Higgins and Butler, that *N. vasinfecta* was an obligate saprophyte and not the ascomycetous stage of *F. niveum.*

Orton (15, 16, 17, 18, 19), from 1902 to 1911, showed that varieties of *Citrullus vulgaris* differed in their resistance to watermelon wilt. He found that an inedible variety of South African origin and the variety Stock Citron were markedly resistant to the disease. He crossed the variety Stock Citron on the wilt susceptible variety Eden and obtained the wilt resistant variety Conqueror. This is probably the first instance known where, by hybridization, a plant variety resistant to a fusarial disease has been developed.

Taubenhaus (38), working in Texas, showed that the organism was widely distributed at different depths in the soil, that it spread more rapidly in field soil where manure was used than where commercial fertilizers were applied and that the pathogen was more active during warm than cool seasons. He also stated that the variety Conqueror was 100 percent resistant under Texas conditions.

It has been shown (22, 23, 24, 25, 26) that: (a) infection followed entrance of the organism through root hairs and through the injured and uninjured hypocotyl; (b) the organism was recovered from all parts of wilting plants and often from healthy appearing plants; (c) the organism flourished at high temperature; (d) it lived on both acid and alkaline media; (e) all commercial varieties tested were susceptible, but certain varieties which produced inedible fruit were resistant; and (f) while susceptibility appeared to be dominant over resistance, inedibility was dominant over edibility in the F_1 of crosses of inedible with edible varieties. The writers (28) reported that: (a) individual plants of susceptible varieties appeared resistant; (b) two edible foreign varieties were resistant; (c) in some cases the F_3 progeny of Conqueror x Kleckley Sweet crosses possessed some resistance; and (d) the F_3 progeny of the variety Halbert Honey x the inedible variety White Seeded were 86 percent resistant. Porter and Henderson (27) reported briefly on the isolation of a wilt resistant genotype by selection in the variety Kleckley Sweet.

Other investigators have contributed to our knowledge of *Fusarium niveum* as follows: Fulton and Winston (5) demonstrated that the organism might be carried on the seed; Maneval (11) found that the organism was viable after being stored on a medium in a test tube at 8° C. for 8 years; Farneti (6) working in Italy stated that cucurbit wilt was caused by *F. niveum*; and Stuckey (37) in a bulletin entitled "Watermelons," in which B. B. Higgins wrote of watermelon diseases, stated that one wilt infected plant in a field indicated that the following year the disease might cause total loss.

PATHOGENICITY AND HOST RELATIONSHIPS OF *FUSARIUM NIVEUM*

INFECTION

Smith (32) demonstrated that infection was induced by the use of infested soil, while the senior writer (26) showed that injections of a spore suspension of *Fusarium niveum* into the hypocotyl and insertion of mycelium into wounded roots were methods by which infection could be induced. Evidence (24) was presented later which indicated that the organism probably

entered the host naturally through root hairs and through the epidermis of the hypocotyl.

PRIMARY INFECTION THROUGH THE RUNNER

It often has been observed in the field that only one end of a runner shows symptoms of wilt infection. In such cases the leaves on the outer end appear normal, while those on the same runner near the crown of the plant are wilted. In other instances, the reverse is true—the leaves next to the crown being normal and those at the outer end wilted. When these conditions occur, usually it is found that new roots have formed where a part of the stem has been covered with soil and that infection has taken place through these small roots.

Runners have been induced to form roots by covering a small portion with moistened infested soil. The outer end became infected, while the main part of the plant remained normal. This has been done with plants growing in disease-free soil as well as with those growing in infested soil. This may offer one explanation why all of the runners of a given plant fail to show symptoms of infection at the same time.

INFECTION THROUGH INJURY CAUSED BY WIND-BLOWN SAND

On June 12, 1928, a severe sand storm injured a large number of plants growing in infested soil. It so happened that alternate rows had been planted with seed of the varieties Stock Citron and Kleckley Sweet. Counts made on June 13 indicated that nearly an equal percentage of plants of these two varieties had been destroyed. On June 17, counts were made again, and the injury appeared equally distributed among the plants of these two varieties. On June 25, however, the plants of the variety Stock Citron had apparently recovered from injury and were growing normally. The plants of the variety Kleckley Sweet still appeared unthrifty, stunted, chlorotic and apparently were making little growth. From June 26 to 30, plants of the variety Kleckley Sweet wilted rapidly and died, while the plants of the variety Stock Citron continued to make normal growth. Plants of the variety Kleckley Sweet not injured by the wind-blown sand, but growing in another part of the field likewise continued to make satisfactory growth, many of them living until Aug. 1 or later. While this evidence is based only on observation, it seems to indicate that plants injured by wind-blown sand may become infected sooner than uninjured plants.

SYMPTOMS

Six symptoms of waterwelon wilt are known. These are: seedling wilt, wilt of more mature plants in the field, damping off, seedling rot, stunting and root canker.

In addition to the symptoms just described, two additional symptoms may appear on plants growing in infested field soil. The first is a chlorotic condition of the leaves. It has been observed repeatedly during August and September, but not until September, 1928, did it appear certain that this chlorotic condition of the leaves was induced by *Fusarium niveum*. Reference is made (p. 164) to field no. 4. It is stated that 286 plants in this 15-acre field appeared resistant on Sept. 1, 1928. These resistant plants were marked and observed on alternate days until Sept. 22. On Sept. 10 it was found that on the 286 plants originally marked, many of the leaves, although they showed no signs of typical wilting, were chlorotic. Others showed no signs either of wilting or chlorosis, but appeared vigorous and normal in every respect. On Sept. 22, when the melons were harvested, it was found that many of the plants which were chlorotic on Sept. 10 were dead because of wilt infection, while the plants which appeared normal and non-chlorotic on Sept. 10 were still normal on Sept. 22. This evidence is not conclusive because cultural evidence is lacking, but this condition has been observed so often in the field, particularly during September, that it is believed that chlorosis of the leaves may be a symptom of infection.

A second symptom, previously undescribed, has been observed constantly on plants growing in infested field soil. It is characterized by general stunting and by the development of numerous open flowers near the outer ends of the runners. The flowers are usually smaller and more numerous than those produced on normal plants, three or four often developing within 2 inches of the outer end of the runner. In most cases, both male and female flowers develop, but before fertilization takes place such plants usually die. Plants on which this condition occurs never have been found to recover, and they usually wilt within a week after this symptom appears. The reason for this excessive blossoming appears to be the shortening of internodes of the infected plants. Non-infected plants seldom produce open flowers within 4 or 5 inches of the outer extremity of a runner. While cultural evidence is again lacking, it appears that the formation of open flowers at the outer extremity of runners may be due to infection by *Fusarium niveum*.

CULTURAL CHARACTERISTICS

Cultures of *Fusarium niveum* have been received from many sections of the United States, and their source is indicated in table I. Single macroconidial cultures were made of nos. 3, 10, 13h, 14a, 15a, 17, 19, 21, 24 and 25, but not of nos. 27, 28, 31, 32, 34, 35 or 36. The pathogenicity of the cultures was determined as follows: 10-day-old cultures growing on steamed *Lycopersicum esculentum* Mill. stems in test tubes were buried in

TABLE I. HISTORY OF CULTURES OF *FUSARIUM NIVEUM*.

Culture number	Locality	Source*
3	Iowa	Isolated in 1926 from an apparently healthy vine
10	Iowa	Isolated in 1926 from a badly rotted secondary root
13h	Iowa	Isolated in 1926 from a peduncle of a wilting vine
14a	Iowa	Isolated in 1926 from the flesh of a melon attached to a wilting vine
15a	Iowa	Isolated in 1926 from seeds of a melon taken from a wilted plant
17	Iowa	Isolated in 1926 from seeds of a melon taken from a wilted plant
19	South Carolina	W. W. Gilbert, Bureau of Plant Industry, U. S. Department of Agriculture
21	Georgia	B. B. Higgins, Ga. Agr. Exp. Sta.
24	Tennessee	C. D. Sherbakoff, Tenn. Agr. Exp. Sta.
25	Tennessee	C. D. Sherbakoff, Tenn. Agr. Exp. Sta.
27	West Virginia	E. C. Sherwood, W. Va. Agr. Exp. Sta.
28	California	J. B. Kendrick, Calif. Agr. Exp. Sta.
29	California	J. B. Kendrick, Calif. Agr. Exp. Sta.
31	Arkansas	V. H. Young, Ark. Agr. Exp. Sta.
32	Mississippi	D. C. Neal, Miss. Agr. Exp. Sta.
34	North Carolina	Isolated from a wilting plant growing in infested soil sent by R. F. Poole, N. C. Agr. Exp. Sta.
35	Iowa	Isolated from a root of a healthy appearing Stock Citron plant
36	California	Isolated from a wilted plant which had grown in infested soil sent by the late J. T. Rosa, Calif. Agr. Exp. Sta.

*Grateful acknowledgment is made to the contributors of cultures of *Fusarium niveum*.

steamed soil in 4-inch greenhouse pots. Surface disinfected seeds were planted and isolations made from wilting plants. Checks were provided by planting surface disinfected seeds in uninfested steamed soil.

Having established the pathogenicity of these 18 cultures, determinations were made of: (a) the relative rate of growth on potato dextrose agar media, (b) ability to produce macroconidia, microconidia and sclerotia, (c) relative degree of pigmentation produced on several kinds of media, (d) ability to acidify or to produce alkalinity in neutral agar culture media, (e) relative rate of starch digestion in steamed rice and (f) comparative morphology of the colonies.

RATE OF GROWTH ON POTATO DEXTROSE AGAR MEDIA

The relative rate of mycelial growth was determined on 4 percent potato dextrose agar, which had been neutralized with a

TABLE II. A COMPARISON OF THE RELATIVE RATE OF MYCELIAL GROWTH OF VARIOUS CULTURES OF *FUSARIUM NIVEUM* AT 30° C. ON POTATO DEXTROSE AGAR HAVING A pH OF APPROXIMATELY 5.6

Culture number	Source	First trial		Second trail		Third trial		Average	
		Cultures 4 days old		Cultures 7 days old		Cultures 6 days old			
		Number plates	Av. diameter colonies cm.	Number plates	Av. diameter colonies cm.	Number plates	Av. diameter colonies cm.	Number plates	Diameter colonies cm.
3	Iowa	3	3.4	2	7.7	4	6.0	9	5.7
10	Iowa	3	3.4	2	6.1	4	5.7	9	5.1
13h	Iowa	3	3.4	2	6.7	4	4.5	9	4.8
14a	Iowa	3	3.3	2	6.1	4	4.5	9	4.6
15a	Iowa	3	3.3	2	6.1	4	5.1	9	4.8
17	Iowa	3	2.8	2	7.5	4	5.0	9	5.1
19	S. C.	3	2.3	2	5.6	4	3.6	9	3.8
21	Ga.	3	2.2	2	4.5	4	4.2	9	3.6
24	Tenn.	3	3.4	2	6.9	4	5.4	9	5.2
25	Tenn.	3	3.6	2	6.3	4	4.6	9	4.8
27	W. Va.	3	2.9	2	6.3	4	4.6	9	4.6
28	Calif.	3	3.5	2	7.3	4	4.5	9	5.1
29	Calif.	3	3.6	2	6.1	4	4.8	9	4.8
31	Ark.	3	2.4	2	6.2	4	4.4	9	4.3
32	Miss.	3	3.5	2	6.3	4	5.0	9	4.9
34	N. C.	3	3.5	2	7.7	4	5.7	9	5.6
35	Iowa	3	3.5	2	8.0	4	5.5	9	5.7
36	Calif.	3	3.4	2	7.2	4	5.8	9	5.5

dilute solution of sodium hydrate and adjusted at 55° C. to a pH of approximately 5.6. Three trials were made, using a total of 9 plates per culture. The results are presented in table II.

The data in table II indicate that there were slight differences in the relative rate of mycelial growth of various cultures of *Fusarium niveum*; such differences were very pronounced when cultures nos. 19 and 21 were compared with cultures nos. 3 and

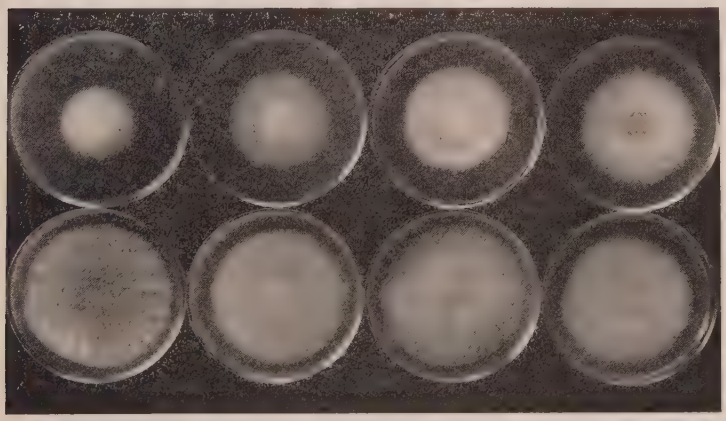

Fig. 1. Relative rate of mycelial growth of different cultures of *Fusarium niveum*.
Upper row: Left to right: 19, 21, 17, 13h.
Lower row: Left to right: 3, 10, 14a, 25.

35. The two former were from South Carolina and Georgia, respectively, while the two latter were from Iowa. Cultures nos. 19 and 21 were consistently slow in growth, as contrasted with no. 3, which always covered the surface of the medium in a petri dish before any of the others under similar conditions. The relative rate of mycelial growth of some of these cultures is shown in fig. 1.

PIGMENTATION

Having determined the relative rate of mycelial growth of these cultures, determinations were made of the ability to produce pigmentation on potato dextrose agar, steamed rice and sterile oats.

Poured plates of potato dextrose agar, having a pH of approximately 5.6, were planted in triplicate with mycelium and spores of the various cultures and incubated at 26° C. Similar trials were conducted several times, but, as subsequent trials were in

TABLE III. PIGMENTATION PRODUCED BY VARIOUS CULTURES OF *FUSARIUM NIVEUM* GROWN ON POTATO DEXTROSE AGAR AT 26° C.

Culture number	Source	Pigmentation
3	Iowa	Usually faintly pink, well distributed through the colony but sometimes in radial bands
10	Iowa	Deeply pink in center of colony, usually with concentric rings of alternate pink and white
13h	Iowa	Usually none, but sometimes faintly yellow to creamy white
14a	Iowa	Pink center with concentric rings of white and pink
15a	Iowa	Deeply pink except for a white periphery
17	Iowa	Dilute pink in radial bands
19	South Carolina	Deep pink to almost blood red- most intensely colored of all cultures. Becomes purple with age
21	Georgia	Dilute pink, well distributed through the colonies. With advancing age, slight purple pigmentation is produced
24	Tennessee	Intensely pink in center of colonies with radial pink bands extending to periphery
25	Tennessee	Pink color practically absent
27	West Virginia	Dilute pink pigmentation confined to the center of the colonies
28	California	Center of colonies deep pink with faint pink bands radiating outward
29	California	Intense pink concentric rings
31	Arkansas	Center dilute pink, color practically absent
32	Mississippi	Almost pure white with few small pink spots
34	North Carolina	Radial bands of pink with occasional blotches of pink
35	Iowa	Deeply pink in center of colonies with dilute pink pigmentation generally scattered through
36	California	Faintly pink concentric rings

close agreement, only the results of the first are presented in table III.

The data in table III show that some cultures of *Fusarium niveum* were unable to produce pigmentation of potato dextrose agar media, and others produced different degrees of pink or red pigmentation. Distinct differences in pigmentation were noted in cultures nos. 13h and 19. Number 13h never produced red or pink pigmentation and only seldom a faint yellow. Number 19 always produced deep pink to blood red pigmentation and, when old, intense purple. As indicated in table III, there were slight differences in the degree and consistency of pigmentation produced by the various cultures.

When these cultures were grown on potato dextrose agar slants in test tubes, the pigmentation was practically identical with that produced on poured plates of the same medium.

These cultures were grown also on steamed rice in test tubes incubated at 26° C. Notes on pigmentation were taken after 6, 11, 15 and 30 days, giving the results which appear in table IV.

TABLE IV. DEGREE* OF PIGMENTATION PRODUCED BY VARIOUS CULTURES OF *FUSARIUM NIVEUM* WHEN GROWN ON STEAMED RICE IN TEST TUBES. CULTURES GROWN IN TRIPLICATE.

Culture number	Source	Degree of pigmentation			
		After 6 days	After 11 days	After 15 days	After 30 days
3	Iowa	2	2	2	2
10	Iowa	2	2	2	3
13h	Iowa	0	0	0	0
14a	Iowa	3	3	3	3
15a	Iowa	4	4	4	4 & 6
17	Iowa	2	3	3	3
19	South Carolina	5	5	5	5 & 6
21	Georgia	4	4	4	4 & 6
24	Tennessee	3	3	3	3 & 6
25	Tennessee	4	5	5	5 & 6
27	West Virginia	3	4	5	5 & 6
28	California	3	3	4	4
29	California	3	4	4	4
31	Arkansas	1	2	3	4
32	Mississippi	2	4	4	5 & 6
34	North Carolina	2	3	3	3
35	Iowa	2	2	2	3
36	California	2	2	3	3

*Range from 1 (dilute pink) to 5 (dark red) and 6 indicating purple.

The degree of pigmentation is indicated as 0, 1, 2, 3, 4, 5, or 6; 0 indicating absence of pigmentation, 5 indicating the most intensely pink or red and 6 indicating purple. It should be noted that the intensity of pigmentation increased slowly, if at all, for each individual culture after 6 days. Culture no. 13h remained colorless. Cultures nos. 3, 14a, 15a, 19 and 21 were as intensely colored after 6 days as after 30, except for the purple pigmenta-

tion which appeared in cultures nos. 15a, 19 and 21. Only 7 of the 20 cultures produced purple pigmentation after 30 days.

Some of these cultures were grown on sterile oats in pint glass jars and the degree of pigmentation noted. The results follow: no. 3—faintly pink in spots; no 14a—deep red to purple; no. 19—deep red to purple; no. 21—red but not as intense as no. 19; no. 24—faintly pink; no. 27—faintly pink; no. 29 —faintly pink; and no. 30—faintly pink.

STARCH DIGESTION

During the pigmentation experiment using steamed rice, a difference in the rate of digestion of the rice in the tubes was noted. To investigate this character further, the digestive power of the various cultures was determined in a triplicate series of test tubes containing steamed rice. The rate of digestion is indicated in table V as follows: 0, 1, 2, 3, 4, 5, or 6; 0 indicating no digestion and 6 most rapid digestion.

The data in table V show that these cultures differed in their ability to digest starch when grown on steamed rice. Cultures nos. 3, 10, 17, 29 and 36 had slight digestive action, while cultures nos. 15a, 19, 25, 27, 31 and 32 had strong digestive action. The remaining cultures were intermediate in their digestive action.

PRODUCTION OF ACID AND ALKALI IN CULTURE MEDIA

Two media were prepared: (a) potato dextrose agar was neutralized with dilute sodium hydrate and 10 cc. poured into petri dishes; (b) 2 percent of agar agar was added to Richard's solution, made neutral with dilute sodium hydrate, and plates were

TABLE V. ABILITY OF VARIOUS CULTURES OF *FUSARIUM NIVEUM* TO DIGEST STARCH PRESENT IN STEAMED RICE.

Culture number	Source	Relative rate of starch digestion			
		After 15 days	After 30 days	After 45 days	After 60 days
3	Iowa	0	0	1	1
10	Iowa	1	1	1	1
13h	Iowa	0	0	0	2
14a	Iowa	2	2	2	2
15a	Iowa	4	4	5	6
17	Iowa	tr.	1	1	1
19	South Carolina	4	5	5	5
21	Georgia	3	3	3	4
24	Tennessee	0	0	1	3
25	Tennessee	2	5	5	5
27	West Virginia	4	6	6	6
28	California	1	1	1	2
29	California	0	0	0	1
31	Arkansas	2	5	5	5
32	Mississippi	2	4	4	6
34	North Carolina	1	2	3	3
35	Iowa	1	2	2	2
36	California	1	1	1	1

TABLE VI. ABILITY OF VARIOUS CULTURES OF *FUSARIUM NIVEUM* TO PRODUCE ALKALINITY OR ACIDITY OF VARIOUS CULTURE MEDIA.

Culture number	Source	Acidity or alkalinity produced				
		On Richard's solution containing 2 percent agar after:	On potato dextrose agar after:			
		7 days	4 days	8 days	10 days	30 days
3	Iowa	−	0*	0	+	+
10	Iowa	−	−	+	−	−
13h	Iowa	−	−	+	−	−
14a	Iowa	−	−	−	−	−
15a	Iowa	+	0	+	−	−
17	Iowa	−	−	−	−	−
19	South Carolina	−	0	−	0	+
21	Georgia	+	0	+	+	−
24	Tennessee	−	−	0	+	−
25	Tennessee	+	0	+	+	+
27	West Virginia	+				
28	California	+				
29	California	−				
31	Arkansas	+				
32	Mississippi	+				
34	North Carolina	−				
35	Iowa	−				
36	California	+				

*In this table 0 indicates that no change occurred, + indicates an acid, and − an alkaline reaction in the medium.

poured. Three plates of each medium were planted with each of the various cultures and the relative acidity or alkalinity of the media recorded after 5 days. The results obtained appear in table VI.

The data in table VI indicate some difference in the ability of the various cultures of *Fusarium niveum* to change the acidity or alkalinity of the culture medium. Cultures nos. 14a and 17 made both media alkaline at all times. Similarly, culture 25 made both media acid. The other cultures were not consistent in causing a change in acidity or alkalinity.

A comparison of the growth habits was made on potato dextrose agar adjusted at 55° C. to a pH of approximately 5.6. Poured plates were planted in triplicate and results recorded after 6 days as indicated in table VII.

Observations recorded in table VII show that cultures nos. 3, 10, 17, 24, 25, 29, 32, 34, 35 and 36 exhibit well marked radial growth, which is not present in the case of nos. 13h, 14a, 15a, 19, 21, 27, 28 and 31. It was not possible to establish positive correlation of the growth habits of the colonies with the locality from which the various cultures were secured.

SPORULATION

The type and the relative frequency of sporulation were determined microscopically: (a) on plate cultures of potato dextrose agar, (b) on agar slants and (c) on steamed Lycopersicum

TABLE VII. COMPARATIVE GROWTH HABITS OF COLONIES OF VARIOUS CULTURES OF *FUSARIUM NIVEUM* WHEN GROWN FOR SIX DAYS ON POTATO DEXTROSE AGAR HAVING A pH OF APPROXIMATELY 5.6.

Culture number	Source	Gross growth habit of the colonies
3	Iowa	Cushion-like center, growth distinctly radial
10	Iowa	Growth distinctly radial, entire colony cushion-like
13h	Iowa	Fairly sparse growth, radial growth not pronounced
14a	Iowa	Cushion-like only in center of colony, radial growth not pronounced
15a	Iowa	Entire colony cushion-like, indistinct radial growth
17	Iowa	Entire colony cushion-like, distinct radial growth
19	South Carolina	Matted growth, not radial, but in concentric rings
21	Georgia	Matted growth, not radial, but in concentric rings
24	Tennessee	Entire colony cushion-like, radiation marked
25	Tennessee	Sparse growth, not cushion-like, radiation marked
27	West Virginia	Cushion-like in center of colony—no radial growth except near the periphery
28	California	Matted growth in center of colony, cushion-like periphery, growth not radial
29	California	Sparse growth—radial growth marked
31	Arkansas	Cushion-like colony, indistinct radial growth
32	Mississippi	Sparse growth, distinctly radial
34	North Carolina	Cushion-like growth, concentric rings and radial growth
35	Iowa	Same as no. 34
36	California	Same as no. 34

stems. The results, which appear in table VIII, indicate that various cultures of *Fusarium niveum* differed considerably in their ability to produce microconidia, macroconidia and sclerotia under the conditions of these experiments.

RELATION OF SOIL TEMPERATURE TO SEEDLING ROT

Field observations indicated that a soil temperature of 22-27° C. was near the optimum for infection. Taubenhaus (38) found wilting to be most rapid during periods when the air temperature was 28° C. or higher. It was shown by the senior writer (24) that the optimum temperature for the rate of mycelial growth of *Fusarium niveum* on potato dextrose agar was between 24-28° C. These findings suggest that the relation of soil temperature to infection should be determined more accurately.

Accordingly, six greenhouse flats were filled with infested field soil and planted with seed of the varieties Kleckley Sweet and Stock Citron in alternate rows. Two flats were then placed

TABLE VIII. TYPE AND FREQUENCY OF SPORULATION OF VARIOUS CULTURES OF *FUSARIUM NIVEUM* ON POTATO DEXTROSE AGAR INCUBATED AT 26° C. RELATIVE FREQUENCY OF SPORES INDICATED PROGRESSIVELY AS 0, 1, 2, 3, 4, 5 AND 6.

Culture number	Source	Type and relative frequency of spores produced						
		On poured plate colonies						Agar slants (sclerotia only)
		Microconidia			Macroconidia			
		Center	2 cm. from center	Periphery	Center	2 cm. from center	Periphery	
3	Iowa	6	6	6	0	0	0	0
10	Iowa	3	2	2	1	1	0	6
13h	Iowa	2	1	1	3	2	1	0
14a	Iowa	6	6	6	1	1	1	3
15a	Iowa	2	1	2	1	1	1	0
17	Iowa	5	4	3	1	0	0	3
19	South Carolina	6	6	6	6	6	6	2
21	Georgia	2	2	2	3	3	2	2
24	Tennessee	2	2	2	2	1	1	1
25	Tennessee	1	1	1	1	1	0	0
27	West Virginia	6	6	6	1	1	1	0
28	California	6	6	6	1	1	1	4
29	California	6	6	6	2	1	1	1
31	Arkansas	1	1	0	0	0	0	0
32	Mississippi	3	3	3	2	2	4	0
34	North Carolina	4	3	2	1	0	0	6
35	Iowa	6	5	5	2	1	1	6
36	California	6	6	6	3	2	1	6

in each of three greenhouses at soil temperatures of 16-18° C., 20-22° C. and 25-28° C. Record was made of the rate of emergence of the plants with the results which appear in table IX.

The data in table IX show that seedling rot was more severe in soil at 16-18° C. than at 25-28° C. After 22 days at 25-28° C. and at 16-18° C. in infested soil, emergence was 96 and 30 percent, respectively, in the case of the variety Kleckley Sweet, while that of the variety Stock Citron was, respectively, 93 and 20 percent. After 22 days at 25-28° C, and 16-18° C. in steamed soil, emergence was, respectively, 98 and 61 percent in the case of the variety Kleckley Sweet, while that of the variety Stock Citron was, respectively, 94 and 54 at the same soil temperatures. After 22 days seedling rot at 16-18° C. had reduced emergence from 61 to 30 percent in the case of Kleckley Sweet, and from 54 to 20 percent for Stock Citron.

In steamed soil 35 days after planting the percentages of plants emerged were high (89 to 98 percent) for both varieties and all soil temperatures (16-28° C.).

In infested soil under similar conditions, seedling rot was severe at the low soil temperature (32 and 26 percent emergence), but not injurious at the high soil temperature (96 and 93 percent emergence). Seedling rot is a manifestation of attack by *Fusarium niveum* at temperatures somewhat lower than the optimum for the rate of mycelial growth of this organism in pure

TABLE IX. INFLUENCE OF SOIL TEMPERATURES BETWEEN 16-18°C. AND 25-28°C. ON THE DEVELOPMENT OF SEEDLING ROT.

Soil temperature. Degrees C.	Variety	Kind of soil	No. of seeds planted	Percentage emergence											
				Days after planting											
				12	14	16	17	18	20	22	24	26	28	30	35
16-18	Kleckley Sweet	Infested	150	0	0	6	16	24	26	30	32	32	32	32	32
20-22	Kleckley Sweet	Infested	150	88	88	88	90	90	90	90	90	90	90	90	90
25-28	Kleckley Sweet	Infested	150	94	96	96	96	96	96	96	96	96	96	96	96
16-18	Stock Citron	Infested	150	0	0	0	13	13	18	20	26	26	26	26	26
20-22	Stock Citron	Infested	150	40	60	60	60	60	60	60	60	60	60	60	60
25-28	Stock Citron	Infested	150	87	93	93	93	93	93	93	93	93	93	93	93
16-18	Kleckley Sweet	Steamed	150	0	1	9	28	39	56	61	71	79	88	88	89
20-22	Kleckley Sweet	Steamed	150	92	92	92	92	92	92	92	92	92	92	92	92
25-28	Kleckley Sweet	Steamed	150	96	96	96	98	98	98	98	98	98	98	98	98
16-18	Stock Citron	Steamed	150	0	0	4	18	49	49	54	69	80	81	88	90
20-22	Stock Citron	Steamed	150	54	69	71	71	71	71	71	77	84	88	89	91
25-28	Stock Citron	Steamed	150	83	88	89	91	91	91	94	94	94	96	96	96

culture. *F. niveum* grows in culture at 15° C., though not as rapidly as at 24-28° C. (24). Emergence is much slower in steamed soil at 16-18° C. than at 25-28° C. It is evident that in infested soil at 16-18° C., the organism has a longer period of time to infect the seedlings. In infested soil at 25-28° C., emergence apparently takes place before the organism causes seedling rot. Watermelon seedlings can emerge at a low (16-18° C.) soil temperature without rotting of the seedlings, if *F. niveum* is absent.

In order to determine more accurately the seedling rot symptoms produced by *Fusarium niveum* at 16-18° C., surface disinfected seeds of the variety Kleckley Sweet were planted in infested soil in greenhouse flats at the rate of 20 seeds per row. Starting on the fifth day after planting, one row of seeds was dug each day for seven consecutive days. Figures 4 and 5 indicate the type of attack. On the fifth day following planting, 10 seeds had germinated. On the sixth day, 14 had germiated. On the seventh day, 16 seeds had germinated, but 6 of the seedlings had been attacked. On the eighth day, 18 had germinated and 11 seedlings had been attacked. On the ninth day 12 of the 18 seedlings were infected, and on the tenth and eleventh days, 14 and 16, respectively, of the seedlings had been attacked. Because in infested soil at 25-28° C. after 16 days about 90 percent of the seedlings had emerged, it is evident that at 16-18° C. infested soil, seedlings are rotted by *F. niveum* before emergence.

RELATION OF SOIL TEMPERATURE AND AGE OF SEEDLINGS TO SEEDLING WILT

INFLUENCE OF SOIL TEMPERATURES

In order to study the relation of soil temperature to wilt a series of experiments was conducted for this purpose. Plant cups were made of heavy cardboard patterned after the plant cups used by Parker (21). They were placed in sterilized greenhouse flats, filled to within an inch of their top with steamed soil, surface-disinfected seeds were planted, and the seeds covered with ½ inch of steamed soil. The flats were placed at a soil temperature of 25-28° C. until about 90 percent of the plants had emerged. Then the seedlings were transplanted into infested soil in greenhouse flats and placed at various soil temperatures. By this method seedlings were produced at a constant temperature in steamed soil, transplanted to infested soil and developed further at different soil temperatures. All plants were of the same age when exposed to infection, and, on account of the steamed soil, there was no danger of seedling rot at the lower temperatures. The data are summarized in table X, and the relation of soil temperature to seedling wilt is shown in fig. 2.

The data in table X show that watermelon wilt was much more serious in soil at 25-28° C. than at 16-18° C. and slightly more serious than at 22-25° C. Within 30 days after they had been transplanted into infested soil at 25-28° C., approximately 100 percent of the plants had died. At the same time, in infested soil at 16-18° C. few plants had wilted. The optimum temperature for the rate of mycelial growth of this organism lies between 24-32° C. (24), hence the optima for wilting and rate of mycelial growth are very close together. While the optima for wilting and rate of mycelial growth of this organism are above 24° C., the optimum soil temperature for the expression of seedling rot, a

Fig. 2. Relation of soil temperature to seedling wilt. Flat on left grown at a temperature of 25-28° C., 84 percent wilt; flat on right at 16-18° C., 6 percent wilt.

TABLE X. THE RELATION OF SOIL TEMPERATURE TO WATERMELON SEEDLING WILT.

Soil temperature. Degrees C.	Trial no.	Percentage of plants wilting																		
		Days after planting																		
		11	13	15	17	18	20	21	22	24	26	28	29	31	33	37	40	41	44	46
16-18	1			0	0		0			0		6		8	25	44		48	81	85
24-26	1			9	45		72			83		100		100	100	100		100	100	100
16-19	2	0	0	0		0		0	0		20		50							
22-25	2	5	6	26		76		91	100		100		100							
16-18	3			0	0		0			0	0	6		10	30	42	52	58	74	
21-24	3			0	10		20			45	65	75		78	84	88	90	91	92	
25-28	3			4	18		36			74	78	84		88	94	94	96	98	100	

different manifestation of attack by *Fusarium niveum* is below 18° C. It has been observed that watermelon seeds germinate slowly when planted in the field in cold soil. Seedling rot may be more important in the field than has hitherto been believed.

AGE OF SEEDLINGS

Field trials in 1927 seemed to indicate that plants of the variety Kleckley Sweet wilted less rapidly when seedlings were transplanted from disease-free to infested soil in the field, than when seeds were planted in naturally infested soil. Accordingly, greenhouse trials were conducted to determine whether transplanting seedlings from steamed to infested soil would change their reaction to wilt. The varieties Kleckley Sweet and Stock Citron were used. Seed of these two varieties was surface disinfected and planted in plant cups containing steamed soil. When the plants were 12 days old, they were transplanted into naturally infested soil and placed in a greenhouse where the soil temperature ranged from 25-28° C., which was near the optimum for mycelial growth in culture and near the optimum for wilt caused by *Fusarium niveum*. The results of this experiment appear in table XI.

TABLE XI. EFFECT OF TRANSPLANTING THE VARIETIES STOCK CITRON AND KLECKLEY SWEET ON INFECTION BY *FUSARIUM NIVEUM*.

Variety	Percentage of plants wilting									
	Days after planting									
	15	17	20	24	28	31	33	35	37	41
Stock Citron	0	0	0	0	6	8	25	36	44	48
Kleckley Sweet	9	45	72	83	100					

The data presented in table XI indicate that the transplanting of either resistant or susceptible varieties has no apparent effect on their resistance because after 28 days 100 percent of the plants of the variety Kleckley Sweet had died. The resistant variety, Stock Citron, remained immune for 24 days following transplanting. The susceptible variety, Kleckley Sweet, did not appear to be any more resistant when transplanted than when seeds were planted in infested soil. Likewise, it appears that the resistant variety, Stock Citron, was no more resistant when transplanted than when seeds were planted in infested soil. Hence, it seems that it is not necessary to produce seedlings of wilt-resistant varieties of watermelons in disease-free soil before they are transplanted into naturally infested soil. This is not in direct agreement with the practice which must be followed with yellows resistant varieties of cabbage, as shown by Jones and Gilman (8) and Stokdyk (36).

RELATION OF SOIL INFESTATION TO WATERMELON WILT

It is a well known fact that if watermelons are grown in the same field for several years in succession watermelon wilt gradually becomes more serious. Even though infested field soil is allowed to remain idle for 16 years and then planted to watermelons, observed effects on watermelon plants indicate that the organism may still be present and viable (24).

In 1926, infested field soil was further infested artificially by the addition of a liberal application of mycelium and spores of *Fusarium niveum* produced on sterile oats. This inoculum was placed in 115 hills, and 109 hills were left naturally infested for a check. The variety Kleckley Sweet was planted on May 25.

No wilt symptoms appeared until after June 21. On June 22 the air temperature suddenly increased and on June 24 the first wilted plants were found in hills which had been artificially infested. The air temperature remained near 30° C. for three weeks. On June 30, 48 percent of the plants exposed to infection in artificially infested soil and 28 percent exposed to natural infection had wilted. On Sept. 20, when the last readings were taken, it was found that 96 percent of the plants exposed to infection in artificially infested soil had died, while 79 percent of those exposed to infection in naturally infested soil had died.

This experiment indicated either that (a) the quantity of inoculum in the naturally infested soil was insufficient to cause 96 percent infection, or (b) the distribution of the inoculum was not uniform. These possibilities gave rise to a series of soil dosage experiments conducted later.

Dosage experiments were conducted with steamed soil (3 parts bench soil to 1 part sand), mixed in various proportions with

TABLE XII. THE RELATION OF THE DEGREE OF NATURAL SOIL INFESTATION TO WILT.

Dosage	Variety	First trial						Second trial								
		Percentage of plants wilting														
		Days after planting														
		26	28	32	34	37	45	22	23	24	25	27	29	30	32	37
Steamed soil	Kleckley Sweet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Steamed soil	Stock Citron	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1:1*	Kleckley Sweet	2	10	16	20	26	52	2	2	2	2	2	12	26	34	44
1:1*	Stock Citron	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1:2*	Kleckley Sweet	2	8	18	34	41	68	0	1	3	3	12	29	38	50	60
1:2*	Stock Citron	0	0	0	0	4	7	0	0	0	0	0	0	7	7	7
1:3*	Kleckley Sweet	1	1	9	21	42	82	3	3	7	7	19	46	59	71	79
1:3*	Stock Citron	0	0	0	0	0	9	0	0	0	0	0	0	6	6	6
Naturally infested	Kleckley Sweet	36	49	81	89	98	100	8	15	23	40	56	80	81	83	89
Naturally infested	Stock Citron	0	1	8	13	16	28	0	0.	0	0	0	0	12	12	31

*1:1 = 1 part steamed to 1 part infested soil.
*1:2 = 1 part steamed to 2 parts infested soil.
*1:3 = 1 part steamed to 3 parts infested soil.

naturally infested field soil taken from an area in the field where plants had died during the summer of 1926. Mixtures 1:1, 1:2 and 1:3, of steamed and naturally infested soil were used. Each type of soil was placed in greenhouse flats, in duplicate, and alternate rows in each flat were planted with seeds of the susceptible variety, Kleckley Sweet and the resistant variety, Stock Citron. It was found that the rate of wilting was much more rapid in infested soil than in such soil mixed with steamed soil. Accordingly, this experiment was repeated with the results which appear in table XII.

The data in table XII show that by mixing steamed soil with field soil infested with *Fusarium niveum*, the rate of wilting of susceptible and resistant varieties of watermelons may be decreased. These data do not show, however, whether this decrease in rate of wilting is because of decrease in quantity of actual infecting material, or whether it simply provided organic matter for the fungus.

In order to determine the reason for the decrease in the rate of wilting of watermelon plants in these experiments, barnyard manure was added to naturally infested soil in various proportions. The addition of barnyard manure to naturally infested soil did not supply as much bulk as did steamed soil, but did supply organic matter on which the fungus could grow. Barnyard manure was mixed with naturally infested soil at the rate of 1:10 and 1:20, and duplicate greenhouse flats were filled with these two mixtures. Two flats were filled with naturally infested soil to which no manure had been added, and one flat was filled with steamed soil to serve as a control. Alternate rows were planted with seed of the varieties Kleckley Sweet and Stock Citron and the flats placed on a greenhouse bench where the air temperature was kept as near 30° C. as possible. The results appear in table XIII.

The data in table XIII indicate that by the addition of barnyard manure to naturally infested soil, the rate of wilting both of susceptible and resistant varieties was markedly increased. The experiment from which the data in table XIII were derived was repeated twice with similar results, indicating that *Fusarium niveum* was more active when the naturally infested soil contained an excess of organic matter. The presence of the barnyard manure may have enabled the organism to grow and produce spores more rapidly than when the manure was absent.

Experiments were conducted also to determine the relation of the degree of soil infestation to the rate of wilting when seedlings grown in steamed soil were transplanted to infested soil. Seed of the Tom Watson variety was surface disinfected and planted in steamed soil in plant cups. The plants grew at soil temperatures of 25-28° C. until the seedlings had produced four

TABLE XIII. THE EFFECT OF BARNYARD MANURE APPLIED TO NATURALLY INFESTED SOIL ON THE OCCURRENCE OF WATERMELON WILT.

Amount of manure	Variety	Percentage of plants wilting							
		Days after planting							
		16	19	21	22	24	26	28	30
None-steamed soil	Kleckley Sweet	0	0	0	0	0	0	0	0
None-steamed soil	Stock Citron	0	0	0	0	0	0	0	0
None-infested soil	Kleckley Sweet	3	18	39	57	68	76	86	93
None-infested soil	Stock Citron	0	0	0	0	0	16	25	32
1:20*	Kleckley Sweet	10	41	78	82	89	91	94	98
1:20*	Stock Citron	0	3	9	28	31	54	56	59
1:10**	Kleckley Sweet	9	35	59	68	81	91	96	98
1:10**	Stock Citron	0	0	0	0	0	21	21	36

*One part manure to 20 parts soil.
**One part manure to 10 parts soil.

leaves. They were then transplanted into greenhouse flats containing (a) steamed soil, (b) naturally infested soil, and (c) a mixture composed of equal parts of steamed and infested soil. The plants were placed at a soil temperature of 22-25° C. and the rate of wilting recorded daily. The results appear in table XIV.

A series of experiments also was conducted to determine the effect of the amount of inoculum on the rate of wilting when a pure culture of *Fusarium niveum* was added to steamed soil. Thus the possibility of interference by other organisms was eliminated. Soil was artificially infested as follows: equal parts of greenhouse bench soil and sand were mixed together and steamed at 28 pounds pressure for 3 hours. This soil was placed in 4-inch pots and infested by adding different amounts of an air dry culture of *F. niveum* which had grown for 11 months on

TABLE XIV. EFFECT OF THE DEGREE OF NATURAL SOIL INFESTATION ON THE RATE OF WILTING, USING SEEDLINGS TRANSPLANTED FROM STEAMED SOIL.

Infection	Percentage of plants wilting							
	Days after planting							
	11	13	15	18	21	22	26	29
Naturally infested soil	5	6	26	76	91	100	100	100
1:1 mixture of steamed and naturally infested soil	0	1	14	59	84	96	98	100
Steamed soil (check)	0	0	0	0	0	0	0	0

sterile, moist oats. The ratio of inoculum to steamed soil varied from 1:1,400 to 1:140 by weight.

Seed of the Kleckley Sweet variety was surface disinfected and planted at the rate of 25 seeds per pot. Triplicate series were employed. The control consisted of steam sterilized soil. The results of three trials appear in table XV.

TABLE XV. RELATION OF THE DEGREE OF ARTIFICIAL SOIL INFESTATION TO WATERMELON SEEDLING WILT.

Ratio of inoculum to soil	Trial no.	Percentage of plants wilting												
		Days after planting												
		11	14	15	17	18	21	22	24	25	26	27	28	30
1:700	1	6		16	28	44		63	75			89	92	
3:700	1	7		59	80	87		97	97			97	100	
5:700	1	30		80	97	99		100						
10:700	1	18		76	89	89		97	99			100		
15:700	1	23		90	100									
Check	1	0		0	0	0		0	0			0	0	
1:1400	2		4	8		21				50				
1:700	2		8	22		51				85				
1:350	2		16	33		64				83				
1:140	2		51	59		81				100				
Check	2		0	0		0				0				
1:1400	3				0	0	4		4		4		8	12
1:700	3				0	6	6		16		16		22	38
1:355	3				20	25	40		40		50		50	75
1:233	3				29	33	37		46		54		66	84
Check	3				0	0	0		0		0		0	0

The data in table XV indicate that the degree of soil infestation determines the rate of wilting of seedlings. At the lower ratios of 1:1,400 and 1:700, wilting was relatively slow, but at ratios of 2:700 and higher, wilting was relatively rapid.

From these dosage experiments it was determined that in order to measure the relative resistance of watermelon varieties and hybrids in the seedling stage, the most accurate method was to use a mixture of inoculum and steamed soil in a ratio of 2:700, growing the seedlings in 4-inch pots. It may be possible to save much time, labor, field space, and expense, by indexing various strains for wilt resistance in the seedling stage.

In addition, these dosage experiments indicated that the quantity of inoculum in the soil and not particularly its even distribution determined whether or not a high mortality resulted. These dosage experiments support field observations which indicate that when watermelons are grown for several successive years in a given field the disease gradually becomes more serious. Taubenhaus (38), Orton (19) and the senior writer (24) have observed the above phenomenon in the field.

TABLE XVI. RELATIVE EFFICIENCY OF THE DUST FUNGICIDES IN THE CONTROL OF SEEDLING ROT AND SEEDLING WILT. GROWN UNDER GREENHOUSE CONDITIONS.

Trial no.	Disinfectant	Soil infestation*	No. of seeds planted	Percentage emergence (Final)	Percentage of plants wilting												
					Days after planting												
					12	14	15	16	17	18	19	20	21	22	29	30	33
1	None (check)	1:1	150	79	5		30				74	78	84	93	97	99	100
1	Bayer Dust	1:1	150	88	0		19				69	72	77	86	88	93	99
1	Merko	1:1	150	67	0		6				39	57	62	72	79	87	95
1	Semesan Jr.	1:1	150	90	0		18				77	91	93	96	97	99	100
2	None (check)	1:2	200	7	14	29	57	89	96	100							
2	Bayer Dust	1:2	100	81	6	18	63	88	92	95							
2	Merko	1:2	100	22	0	27	41	63	91	95							
2	Semesan Jr.	1:2	100	99	13	30	56	85	98	99							

*Soil infestation of 1:1 means that the soil used consisted of a mixture of equal parts of steamed and naturally infested soil. A ratio of 1:2 indicates that one part of steamed and two of naturally infested soil were mixed together and used.

GREENHOUSE TRIALS WITH DUST FUNGICIDES IN THE CONTROL OF SEEDLING ROT AND SEEDLING WILT

Soon after these investigations were begun in 1926, difficulty was experienced in the greenhouse in securing satisfactory stands of susceptible varieties in heavily infested soil. It was found that seedling rot caused necrosis of the hypocotyl and radicle before emergence of the cotyledons. Experiments were undertaken, therefore, to determine whether seedling rot could be prevented by seed disinfection.

Accordingly, three lots of seed of the Keckley Sweet variety were disinfected, respectively, with Bayer Dust, Merko and Semesan Jr. and planted in two kinds of soil held at a soil temperature of 16-19° C. The soil used in trial no. 1 (table XVI) consisted of a mixture of equal parts of steamed and naturally infested soil. The soil used in trial no. 2 (table XVI) consisted of a mixture of 1 part of steamed and 2 parts of naturally infested soil. Record was made of the rate of emergence and of the rate of wilting with the results which appear in table XVI.

The data in table XVI indicate that the rate of seedling emergence was increased by seed disinfection and that the rate of wilting was slightly less rapid when seed was disinfected. In trial no. 1, using soil less heavily infested than that used in trial no. 2, final emergence from untreated seed was 79 percent, while the emergence from seeds treated with Bayer Dust and Semesan Jr. was, respectively, 88 and 90 percent. Merko, apparently, caused some seed injury as emergence was only 67 percent. Plants produced by untreated seed wilted slightly more rapidly than those from seed disinfected with Bayer Dust and Merko, but the difference in the rate of wilting was not great and of doubtful significance.

In trial no. 2, using soil more heavily infested than in trial no. 1, final emergence from untreated seed was only 7 percent, while the emergence from seed treated with Bayer Dust and Semesan Jr. was, respectively, 81 and 99 percent. Merko again seemed to cause some injury as emergence when it was used was only 22 percent. As in trial no. 1, the rate of wilting was slightly more rapid from untreated seed than from plants produced by the disinfected seed, but, again the results, although quite consistent, are not particularly significant.

Seven days after planting (trial no. 2 in table XVI) the untreated seeds were removed from the soil and examined for evidence of seedling rot. It was found that in 95 percent of the seeds, germination had occurred, but before the cotyledons emerged from the soil, the hypocotyl, the roots or both had been destroyed. In some cases, the cotyledons reached the surface of the soil and began to break the soil crust, but such seedlings were

destroyed before emergence was complete. Isolations were made from such infected seedlings, and reinoculations made into watermelons. It was found that *Fusarium niveum* was recovered from about 50 percent of the infected seedlings. The effect of seed disinfection on the prevention of seedling rot is shown in figs.3, 4 and 5. Seed treatment seemed to retard the activity of the plant parasite which permitted the seedlings to live longer. In each trial the check lots died first. There seemed to be some difference in the fungicidal value of different dusts.

Fig. 3. Seedling rot control by seed disinfection on the Kleckley Sweet variety. Middle row and outside rows planted with non-disinfected seed. Remaining five rows planted with disinfected seed.

RELATION OF AIR TEMPERATURE TO WATERMELON WILT IN TWO INFESTED FIELDS

The relation of air temperature to the rate of wilting was studied in two infested fields in 1927 and 1928. The soil in field no. 1 was known to be more heavily infested than in field no. 2. Except in field no. 2 in 1928, the varieties Kleckley Sweet and Tom Watson were planted. Numerous commercial varieties and selections were planted in field no. 2 in 1928.

The percentage of wilt was determined by making stand counts at intervals of 5 to 10 days from the date of emergence of the first plants until the end of the growing season. The difference in stand between two successive counts was divided by the stand at the time of the count immediately preceding. The percentage

TABLE XVII. RELATION OF AIR TEMPERATURE TO THE RATE OF WILTING IN 1927. FIELD NO. 1. PLANTED MAY 28. INITIAL STAND 1,455 PLANTS.

Dates of readings	Average percentage daily wilting since last reading	Average day hours since last reading						
		Above 32°C.	Above 29°C.	Above 27°C.	Above 24°C.	Below 18°C.	Below 15°C.	Below 13°C.
July 1	1.9	0.9	1.6	3.3	4.8	2.1	1.1	0.6
July 7	4.8	1.2	2.1	5.5	7.6	3.1	1.2	0.2
July 12	3.6	0.5	2.7	4.2	5.7	2.1	0.2	0.1
July 19	1.9	1.0	1.8	4.3	5.0	0.9	0.4	0.1
July 29	3.3	1.0	1.8	4.7	5.2	2.2	0.7	0.2
August 6	1.5	0.2	0.7	2.5	4.1	6.4	2.5	1.2
August 12	1.8	0.3	0.9	2.5	4.3	4.8	3.1	2.1
August 20	2.4	1.1	1.8	2.9	4.8	3.3	2.6	1.8

of wilt was then divided by the number of days which had elapsed since the last reading, giving the average percentage of wilt each day.

The air temperature was recorded automatically by a Friez soil and air thermograph. The total number of hours that the air temperature was above a certain point was determined for the interval between the dates of successive stand counts. This number was divided by the number of days which had elapsed since the previous reading, giving the average number of hours per day that the air temperature was above 21° C., 24° C., etc.

The relation between the average percentage of daily wilt since the last reading and the average number of hours per day that the air temperature was above 21° C. and 24° C., are shown in tables XVII, XVIII, XIX, XX and XXI.

Examination of the data in tables XVII to XXI, inclusive, shows that the longer the duration of the warm weather in a given period of time, the higher the percentage of wilt which

TABLE XVIII. RELATION OF AIR TEMPERATURE TO THE RATE OF WILTING. 1927. FIELD NO. 1. PLANTED JULY 7. INITIAL STAND 1,317 PLANTS.

Dates of readings	Average percentage daily wilting since last reading	Average day hours since last reading							
		Above 35°C.	Above 32°C.	Above 29°C.	Above 27°C.	Above 24°C.	Below 18°C.	Below 15°C.	Below 13°C.
July 20	2.0	0	0	0	0.5	1.0	3.0	0	0
July 21	1.1	0	0	0	0	0.5	0	0	0
Ju y 22	1.0	0	0	0	0	0	4.0	0	0
July 23	14.8	0	0	0	3.5	5.0	5.5	4.0	1.0
July 24	2.1	0	0	0	2.0	3.0	5.0	4.5	0
July 25	10.3	0	0	0	5.0	5.0	2.0	0	0
July 28	24.7	1.0	8.0	12.0	18.0	22.0	3.5	0	0
July 29	8.2	0	1.0	2.0	4.0	5.0	0	0	0
July 30	11.7	0	0	0	5.0	7.0	5.0	0	0
Aug. 1	13.7	0	0	3.0	4.5	9.5	2.0	0	0
Aug. 2	19.6	0.7	1.5	6.0	7.5	11.5	0	0	0
Aug. 3	7.7	0	0	0	1.0	4.0	8.0	5.0	4.0
Aug. 4	10.7	0	0	0	2.5	3.5	5.0	4.0	3.0
Aug. 6	17.9	0	2.0	4.0	7.0	9.0	3.0	1.0	0
Aug. 8	18.6	0.5	5.0	8.0	11.0	16.0	3.0	1.0	0

followed. In table XVII, it is shown that on July 7 the average daily wilt since last reading was 4.8 percent, the most rapid wilting during the time records were taken. The average number of hours per day that the air temperature was above 24° C. was 7.6; the average number above 27° C. was 5.5; the average number above 29° C. was 2.1; and the average number above 32° C. was 1.2. In all except one case, at 29° C., the average number was greater than at other times during the season. On July 12, the average percentage of daily wilt since last reading was 3.6 or 1.2 percent less than on July 7. The average number of hours per day that the air temperature was above 24°, 27°, 29° and 32° C. was less for the period ending on July 12 than on July 7.

TABLE XIX. RELATION OF AIR TEMPERATURE TO THE RATE OF WILTING 1927. FIELD NO. 2. PLANTED MAY 26. INITIAL STAND 2,328 PLANTS.

Dates of readings	Average percentage daily wilting since last reading	Average day hours since last reading						
		Above 32°C.	Above 29°C.	Above 27°C.	Above 24°C.	Below 18°C.	Below 15°C.	Below 13°C.
July 1	2.7	1.1	1.3	3.6	4.8	1.4	1.0	0.8
July 8	3.5	1.6	2.4	5.2	7.0	2.7	1.0	0.1
July 13	3.2	0.5	2.7	4.2	5.7	2.1	0.5	0.1
July 19	2.6	1.1	2.7	4.3	5.6	1.5	0.4	0.1
July 29	3.2	1.0	1.8	4.7	5.2	2.2	0.7	0.2
August 6	2.6	0.2	0.7	2.5	4.1	6.4	2.5	1.0
August 14	2.1	0.4	0.9	3.3	3.9	6.1	2.9	1.8

The data in table XVIII show even a more apparent correlation than in table XVII. Between July 25 and 28, 24.7 percent of the plants died. During this 3-day period the air temperature was above 35° C. for 3 hours; above 32° C. for 24 hours; above 29° C. for 36 hours; above 27° C. for 54 hours, and above 24° C. for 66 hours. Between July 28 and 29, 8.2 percent of the plants wilted, and during this period the air temperature was never above 35° C.; above 29° C. for 2; above 27° C. for 4, and above 24° C. for 5 hours.

Similar correlations are evident from the data in tables XIX, XX and XXI, indicating that continued warm weather (at or above 21° C.) is necessary in order to bring about wilting under field conditions. Continued warm weather apparently is a precursor of the expression of symptoms of watermelon wilt.

STUDIES ON THE CONTROL OF WATERMELON WILT

In attempting to develop control measures for watermelon wilt, investigation has been made of: (a) the value of treating infested soil with lime, commercial fertilizers and barnyard manure; (b) the influence of starting plants in disease-free soil and transplanting to infested soil; (c) the extent of varietal resis-

Fig 4. Seedling rot control by seed disinfection on the variety Stock Citron. Seeds on the left treated, those on the right not treated. Seeds removed from soil seven days after planting. Soil heavily infested with *Fusarium niveum*. The variety Stock Citron appears more resistant to seedling rot than the variety Kleckley Sweet. (See fig. 5.)

Fig. 5. Seedling rot control by seed disinfection of the Kleckley Sweet variety. Upper group of seeds not treated, lower group treated. Seeds removed from soil seven days after planting. Soil heavily infested with *Fusarium niveum*.

Fig. 6. The varieties White Seeded and Kleckley Sweet showing comparative resistance to wilt in artificially infested soil. Left to right: (a) White Seeded (resistant) and (b) Kleckley Sweet (susceptible).

Fig. 7. F_2 fruits of a cross of the variety Conqueror with the variety Kleckley Sweet.

Fig. 8. Fruit types of the varieties White Seeded (middle and right) and Kaolo (left).

Fig. 9. Relative resistance to seedling wilt of open-pollinated selections from the variety Kleckley Sweet. Fifteen percent wilt in the two pots on the left (B3) and 89 percent in the two pots on the right (B17). (Wilted plants were removed from the pots when the wilt symptoms appeared.)

Fig. 10. Relative resistance to seedling wilt of the F_3 of crosses of the variety Conqueror on the variety Excel. Thirty-six percent wilt in the two pots on the left (43-S1-S1) and 91 percent in the two pots on the right (43-S1-S4). (Wilted plants were removed from the pots when the wilt symptoms appeared.)

Fig. 11. Relative resistance to seedling wilt of the F_4 of the crosses of the variety White Seeded on the variety Halbert Honey. Seven percent wilt in the two pots on the left (156-S2-S2-S1) and 71 percent in the two pots on the right (156-S2-S2-S2). (Wilted plants were removed from the pots when the wilt symptoms appeared.)

TABLE XX. RELATION OF AIR TEMPERATURE TO WATERMELON WILT. FIELD NO. 1. PLANTED MAY 23, 1928. INITIAL STAND 1,886 PLANTS.

Dates of readings	Average percentage daily wilting since last reading	Average day hours since last reading								
		Above 35°C.	Above 32°C.	Above 29°C.	Above 27°C.	Above 24°C.	Above 21°C.	Below 18°C.	Below 15°C.	Below 13°C.
June 18	3.1	0	0.2	2.8	4.4	7.8	11.6	4.6	3.8	0.1
June 25	2.2	0	0.3	1.4	4.5	8.5	12.4	3.8	0.6	0
June 29	1.8	0	0	0	1.0	4.0	5.6	6.5	5.3	2.0
July 5	4.2	0.2	2.6	4.7	8.3	13.3	17.3	4.8	1.2	0
July 10	5.8	1.4	3.4	8.2	11.0	14.5	18.0	1.2	0	0
July 16	2.6	0	1.1	3.6	6.5	9.8	14.8	4.0	1.5	0
Aug. 7	2.8	0	1.7	4.1	8.1	11.4	16.4	1.8	1.1	0.5
Aug. 14	3.4	1.4	3.0	6.7	9.8	12.4	16.3	3.0	2.0	0.7
Aug. 30	2.4	0.4	2.0	3.2	6.0	9.8	14.6	4.6	2.9	0.9

TABLE XXI. RELATION OF AIR TEMPERATURE TO WATERMELON WILT. FIELD NO. 2. PLANTED MAY 24, 1928. INITIAL STAND 3,158 PLANTS.

Dates of readings	Average percentage daily wilting since last reading	Average day hours since last reading								
		Above 35°C.	Above 32°C.	Above 29°C.	Above 27°C.	Above 24°C.	Above 21°C.	Below 18°C.	Below 15°C.	Below 13°C.
Insert head										
June 18	1.8	0	0.2	2.8	4.4	7.8	11.6	4.6	3.8	0.1
June 25	1.6	0	0.3	1.4	4.5	8.5	12.4	3.8	0.6	0
June 29	0.9	0	0	0	1.0	4.0	5.6	6.5	5.3	2.0
July 5	2.2	0.2	2.6	4.7	8.3	13.3	17.3	4.8	1.2	0
July 10	3.4	1.4	3.4	8.2	11.0	14.5	18.0	0.2	0	0
July 16	1.8	0	1.1	3.6	6.5	9.8	14.8	4.0	1.5	0
Aug. 7	1.3	0	1.7	4.1	8.1	11.4	16.4	1.8	1.1	0.5
Aug. 14	2.1	1.4	3.0	6.7	9.8	12.4	16.3	3.0	2.0	0.7
Aug. 30	1.3	0.4	2.0	3.2	6.0	9.8	14.6	4.6	2.9	0.9

tance within *Citrullus vulgaris*, and (d) the development of wilt resistant strains by selection and hybridization.

EFFECT OF SOIL TREATMENT ON THE WILT PATHOGENE

Having found (24) that *Fusarium niveum* grew more slowly on artificial culture media at a pH of 8.4 than at 5.8, it seemed desirable to determine the influence that the application of lime to infested field soil would have on the rate of wilting.

In 1927, field trials were conducted to determine the effect on watermelon wilt of lime, commercial fertilizer (2-8-5), and barnyard manure when infested soil was treated with these materials. These materials were applied to infested soil before planting the seed. Although slight differences in the rate of wilting in the various plots were apparent during the growing season, yet, on Sept. 16, no measurable differences could be noted.

DEVELOPMENT OF WILT ON TRANSPLANTED WATERMELONS

In connection with investigations of seedling rot, it was found that infection might take place immediately following seed germination and so prevent emergence. It seemed advisable, therefore, to investigate the possibility of control by growing seedlings in disease-free soil and then transplanting them to infested field soil. As preliminary trials in 1926 seemed to indicate that this practice was worthy of further trials, in 1927 disinfected seed of the variety Kleckley Sweet was planted in wilt-free soil in plant cups and the seedlings were transplanted into infested soil in the field. Counts of wilted plants on June 27 showed that the transplants were wilting less rapidly than those where the seed was planted directly in the field; on July 29 there was little difference, and on Sept. 9 the percentage of wilted plants was the same. Similar trials conducted in 1928 again indicated that this practice had no effect on infection of the variety Kleckley Sweet.

RELATIVE WILT RESISTANCE OF VARIETIES OF *CITRULLUS VULGARIS*

On the basis of edibility, the varieties of *Citrullus vulgaris* may be divided arbitrarily into two groups: (a) the citron group and (b) the watermelon group. The flesh of the varieties of the citron group is relatively inedible; usually sour or bitter; white, yellow, or salmon tinted; and often hard or coarse. The flesh of the varieties of the watermelon group is relatively edible; sweet; white, yellow, pink, or red; and soft.

EDIBLE AMERICAN VARIETIES

Orton (17) tested the relative wilt resistance of approximately 100 edible American and Russian varieties and stated that all of

them were highly susceptible. He also tested the variety Stock Citron and a citron variety of South African origin and found both of them to be relatively resistant. Taubenhaus (38) used fewer edible varieties than Orton and found all of them, except the variety Conqueror, which was 100 percent resistant, to be over 60 percent susceptible. The senior writer (25) tested 52 edible varieties in 1926 and, while all of them were susceptible, yet there seemed to be a difference in the rate of wilting at different times during the growing season, depending upon the variety. All varieties were not completely susceptible, but there was at least 96 percent wilt in all of them at the end of the growing season. A few plants of the varieties Kleckley Sweet, Excel and Long Light Icing, did not wilt. This indicated a slight difference in the relative resistance of edible American varieties, since the majority of the varieties tested were 100 percent susceptible to wilt.

In order to test further the relative wilt resistance of edible American varieties, in 1927 and 1928 seeds of the following named watermelon varieties were planted in infested field soil at Conesville and Fruitland, Iowa: Alabama Sweet, August Rattlesnake, Black Seeded Angeleno, Black Seeded Chilian, Carolina Bradford, Cold Mountain, Cole's Early, Conqueror, Cuban Queen, Dixie Belle, Excel, Fordhook Early, Florabama, Florida Favorite, General Pershing, Georgia Rattlesnake, Golden Honey, Halbert Honey, Ice Cream, Indian Chief, Irish Gray, King and Queen, Kleckley Sweet, Klondike, Kolb's Gem, Long Light Icing, New Perfection, Oquawka, Oregon, Peerless, Radio, Reuter's Rattlesnake, Schochler, Stone Mountain, Success, Sun Moon and Stars, Sweetheart, Sweet Siberian, Thurmond Gray, Tom Watson, White Seeded Angeleno, White Seeded Chilian, White Watson, Winter, Winter Queen, Wondermelon and Yellow Fleshed Ice Cream. At the end of the growing season there seemed to be little difference in the susceptibility of these varieties to wilt. In 1926, however, plants of certain varieties wilted less rapidly than others during June and July. By Sept. 1, 98 percent of the plants of all the varieties tested had died. Based on relative susceptibility on Aug. 1, the varieties referred to were not equally susceptible, while on Sept. 1, differences in relative susceptibility were obscured.

In addition to the field trials just described, extensive trials were conducted in the field with seedlings during July and August, 1927, to determine their relative varietal resistance. Planting was purposely delayed until July so that the soil temperature would be nearer the optimum for the rate of growth of the organism. Environmental conditions were made more favorable for infection by artificially infesting the naturally in-

fested soil with a pure culture of *Fusarium niveum* which had grown for 3 months on sterilized oats. A mixture of equal parts of inoculum and sand was placed in the bottom of a shallow furrow and covered with soil, then seeds were planted about 2 inches above the inoculum. The varieties used were: Alabama Sweet, Conqueror, Excel, Florida Favorite, Georgia Rattlesnake, Preserving Citron, Halbert Honey, Kleckley Sweet, Radio, Stock Citron, Sun Moon and Stars, Sweetheart, Thurmond Gray, Tom Watson and Wondermelon. Three replications of each were planted on July 7 when the soil temperature was 28° C. or near the optimum favorable to the growth and infection by the organism. Counts on emergence and rate of wilting were made daily from July 7 until Aug. 18, inclusive. The daily wilting counts seemed to indicate little difference in the relative resistance of these varieties. The variety Stock Citron, however, was 96.5 percent resistant on July 25 and 49 percent resistant on Aug. 8. The variety Sweetheart succumbed slowly, showing some resistance on July 22, and by Aug. 8 as many plants had died as in the other commercial varieties. The results of this trial appear in table XXII and indicate a variation in the relative resistance to wilt of the varieties tested. Such variation is more evident during the growing period than at the end of the season.

RELATIVE WILT RESISTANCE OF EDIBLE FOREIGN VARIETIES

In addition to the trials with American edible varieties, many edible varieties[1] of foreign origin have been tested for wilt resistance. Forty-two edible foreign varieties have been grown during the three years (1926-1928) on infested soil at Conesville and Fruitland, Iowa, and of this number only one was found to be relatively wilt resistant. Seed of this variety (Japan No. 7) was received from Professor Takewo Hemmi of Japan and its history is unknown to the writers. The plants are prolific and the melon is small, oval, early maturing, and has yellow skin and white flesh. It is not particularly palatable and is considered valueless except for hybridizing with desirable commercial varieties.

RELATIVE WILT RESISTANCE OF INEDIBLE VARIETIES OF *CITRULLUS VULGARIS*

In addition to edible varieties, many inedible varieties of *Citrullus vulgaris* were tested for resistance to wilt during 1926, 1927 and 1928. Of these varieties, seed of Preserving Citron and Stock Citron were secured from local seedsmen; two varie-

[1]The edible foreign varieties tested were collected by the following, to whom we are deeply indebted: Dr. E. W. Lindstrom from France; Prof. Takewo Hemmi from Japan; Dr. B. N. Uppal from India; Dr. E. V. Abbott from Peru; Dr. P. H. Rolfs from Brazil; Dean C. F. Curtiss from Jugo-Slavia; and Dr. R. H. Porter from China.

TABLE XXII. RELATIVE RESISTANCE OF SOME EDIBLE VARIETIES OF *CITRULLUS VULGARIS* TO WATERMELON WILT IN ARTIFICIALLY INFESTED FIELD SOIL AT CONESVILLE, IOWA, JULY AND AUGUST, 1927.

Variety	Percentage of plants wilting												
	Days after planting												
	12	13	14	15	16	17	18	21	22	23	25	26	36
Alabama Sweet	2.4	3.6	4.8	7.2	15.7	20.5	24.1	51.8	57.8	61.4	67.4	73.5	96
Conqueror	4.7	9.1	10.8	10.8	29.1	38.8	42.9	56.1	58.8	64.1	74.4	76.8	98
Excel	14.9	19.4	22.7	22.7	31.4	38.8	64.1	64.1	68.7	70.1	83.4	80.6	91
Florida Favorite	10.2	14.2	16.4	16.4	28.3	31.5	38.6	51.9	63.9	70.0	73.2	78.7	96
Georgia Rattlesnake	8.0	10.2	13.7	17.0	43.2	43.2	60.2	72.7	78.4	84.1	84.2	86.3	93
Halbert Honey	7.5	8.4	11.2	12.1	21.5	24.3	27.1	35.5	35.5	43.0	59.8	60.7	99
Kleckley Sweet	6.6	6.6	6.6	17.7	17.7	22.2	42.2	43.3	46.6	55.5	63.3	66.8	99
Stock Citron (control)	1.7	1.7	1.7	1.7	1.7	1.7	3.5	19.3	24.6	29.8	35.1	49.5	51
Preserving Citron (control)	0	3.6	3.8	3.8	28.6	32.1	35.7	75.0	82.1	85.7	85.7	85.7	86
Radio	3.5	3.5	3.5	6.8	38.0	38.0	51.7	82.8	82.8	93.1	93.1	93.1	96
Sun Moon and Stars	2.3	6.1	6.1	6.1	16.1	19.8	21.4	33.6	35.9	42.7	58.0	61.9	98
Sweetheart	0	0	0	1.7	12.8	19.1	34.0	48.0	51.1	51.1	63.8	65.8	99
Thurmond Gray	1.5	3.7	6.1	6.1	19.8	20.3	25.0	40.1	43.9	45.4	55.3	59.8	100
Tom Watson	2.2	5.7	8.6	9.4	17.2	20.1	23.7	46.9	48.9	56.1	65.5	71.8	100
Wondermelon	1.5	3.0	4.8	6.0	16.6	19.7	33.3	36.3	62.1	66.6	72.7	72.7	100

ties from Africa which had been sent to the Office of Vegetable and Forage Diseases, United States Department of Agriculture, and reported resistant in the trials of W. A. Orton,[2] and the remainder were secured from various seedsmen, scientists and agricultural explorers in foreign countries.[3]

The relative wilt resistance of nine varieties of watermelons producing inedible melons (Citron group) is shown in table XXIII. It is shown that resistance varied from 58 percent (variety Preserving Citron) to 100 percent (variety Majorta and variety Mammoth White), while the edible commercial variety Kleckley Sweet was susceptible. Three varieties were tested for 3 years and of these the varieties Kafir and White Seeded were highly resistant (approximately 98 percent), while the average resistance of the Preserving Citron was 65 percent. Resistance is relative among the varieties which produce inedible fruit, as with those varieties which produce edible fruit.

TABLE XXIII. RELATIVE RESISTANCE OF INEDIBLE VARIETIES OF *CITRULLUS VULGARIS* TO WILT.

Variety	Source	Percentage of resistance in		
		1926	1927	1928
No. 30839	France			63
No. 30739	France			59
Preserving Citron	United States	66	71	58
Stock Citron	United States			91
Kafir	Africa	98	96	99
Majorta	Africa			100
White Seeded	Africa	98	99	97
Tsama	Africa			96
Mammoth White	Africa			100
Kleckley Sweet (check)	United States	trace	trace	trace

ISOLATION OF WILT RESISTANT STRAINS OF WATERMELONS BY SELECTION WITHIN COMMERCIAL VARIETIES

Many varieties of plants resistant to fusarial wilt diseases have been isolated by selection of resistant genotypes from susceptible varieties. The success of Jones et al. (8, 9, 10), Walker et al. (39, 40), and Melhus et al. (12) with cabbage; Pritchard (29), Elliott (4), and Edgerton et al. (2, 3) with tomatoes, and of Orton et al. (13, 20) with cotton has demonstrated the practicability of selection for fusarial wilt resistance.

TRIALS WITH THE KLECKLEY SWEET VARIETY

In 1927, seed of the Kleckley Sweet variety was planted on

[2]This information was taken from correspondence with W. W. Gilbert of the Office of Vegetable and Forage Diseases, United States Department of Agriculture.

[3]The name and source of the inedible varieties tested follow: Tsama, Kafir, White Seeded, Mammoth White, and Majorta from Africa; Nos. 30839 and 30739 from France; Stock Citron from Burrell Seed Company of Rocky Ford, Colorado, and Preserving Citron from Vaughan Seed Company, Chicago, Illinois. Grateful acknowledgment is made to Dr. E. W. Lindstrom for seeds secured in France and to W. W. Gilbert for seed of the varieties Kafir and White Seeded. Seed of the varieties Majorta, Tsama and Mammoth White was secured from the C. Starke Company, Ltd., of Cape Town, Africa.

three acres of infested soil at Conesville, Iowa, the initial stand being 11,260 plants. Wilt infection was evident on June 2, and infection rapidly increased during the growing season. By July 15 and Sept. 20, respectively, 35 and 98 percent of the plants had wilted. Starting on July 21, flowers were self-pollinated, but on Sept. 20 only 11 selfed melons remained on living vines in the field. Only 1 of these 11 melons matured on a living vine. This self-pollinated selection was designated as K-S4[4] and the open pollinated selections as K-2, K-4, K-10, K-11, K-15, K-16, K-17, K-18, K-19 and K-20.

Seed of the selection K-S4 and of the selections designated as K-2, K-4, K-10, K-11, K-15, K-16, K-17, K-18, K-19 and K-20, was planted in a heavily infested, isolated, 2-acre field in 1928. At least 4, and in some cases as many as 10 replications were made of each selection. Evidence that the soil was heavily infested had been obtained in 1926 and 1927, where commercial varieties, Kleckley Sweet and Tom Watson, showed 98 and 99 percent wilt, respectively. The rows were 20 rods long and 7 feet apart, each 20-rod row was divided into four equal sections, and 20 hills planted in each section at the rate of 4 to 8 seeds per hill. The check rows were planted with seed of the Kleckley Sweet variety. The initial stand and the rate of wilting during the growing season appear in table XXIV.

The data in table XXIV indicate that there was a decided difference in the relative wilt resistance of selections from the Kleckley Sweet variety when these selections were grown on heavily infested soil. Selections K-15, K-16 and K-17 were, completely susceptible, while selections K-18, K-10 and K-19 were, respectively, 81, 88 and 89 percent susceptible. It should be noted that selections K-15, K-16, K-17, K-18, K-10 and K-19 were from open-pollinated fruits. Selection K-S4, the self-pollinated strain of the Kleckley Sweet variety, was more resistant than the open-pollinated selections as 47 percent of the plants were alive on Sept. 15, 1928.

It is interesting to note the relative resistance of these 11 selections on consecutive dates during the summer. On June 18, when the second count was made, there were few striking differences in the rate of wilting: K-S4, on June 18, was no more resistant than several open-pollinated selections. On June 25, differences in rate of wilting appeared. The selections K-S4, K-16 and K-19 showed, respectively, 13, 40 and 46 percent wilt. Four days later there was no further relative change. On July 5, however, selections K-11 and K-19 showed 52 and 53 percent wilt, respectively. The percentage of wilt of K-S4 increased slowly, even though soil and air temperatures were

[4]This selection has since been described as Pride of Muscatine. Iowa Agr. Exp. Sta., Cir. 125. 1931.

near the optimum for infection by *Fusarium niveum*. Many of the open-pollinated selections continued to wilt rapidly during July. On Aug. 1 wilt of selections K-4, K-16, K-19, K-11 and K-15 was, respectively, 88, 71, 69, 69 and 69 percent, while the percentage of wilt of K-S4 remained the same.

During August and the first 2 weeks of September, the percentage of wilt of all selections increased until on September 15, selections K-15, K-16 and K-17 were 100 percent wilted, while K-S4 showed only 53 percent. Selections K-18, K-19 and K-11 were wilted to the extent of 81, 89 and 96 percent, respectively.

Further evidence that K-S4 was relatively resistant in 1928 is presented in the column in table XXIV headed "Number ripe melons harvested." It will be noted that this selection (K-S4) produced 59 ripe melons. In addition, K-S4 produced 14 small melons which did not mature seed. The 34 resistant plants of K-S4 produced 73 melons, or slightly more than an average of 2 melons per plant. This yield is considered satisfactory for the production of a profitable crop, even in disease-free soil. It is evident also that the number of ripe melons harvested may be positively correlated with the relative resistance of the various selections.

TABLE XXIV. RELATIVE WILT RESISTANCE OF SOME SELECTIONS FROM THE KLECKLEY SWEET VARIETY GROWN ON HEAVILY INFESTED SOIL AT CONESVILLE IN 1928.

Selection	Number of replications	Initial stand June 1	Percentage of wilt									Number ripe melons harvested
			June 18	June 25	June 29	July 5	July 10	July 16	Aug. 1	Aug. 16	Sept 15 final	
K-S4*	4	72	11	13	19	26	26	26	26	34	53	59
K-2	4	60	12	18	20	28	33	42	63	85	98	4
K-4	6	29	4	28	52	69	79	83	88	94	98	1
K-10	10	113	6	29	37	38	41	45	58	75	88	26
K-11	10	88	10	26	38	52	53	54	69	90	96	3
K-15	4	50	22	30	42	48	52	54	69	92	100	0
K-16	4	45	31	40	41	49	53	53	71	96	100	0
K-17	4	69	4	14	26	37	41	45	63	89	100	0
K-18	5	79	9	30	33	51	53	54	66	76	81	10
K-19	7	89	12	46	48	53	56	61	69	76	89	5
K-20	10	144	13	21	29	42	43	44	68	95	98	1
Total												109

*Now known as Pride of Muscatine.

Additional evidence of the resistance of K-S4 appears in table XXV in which the resistance of the selections adjoining and adjacent to the four replications of K-S4 is recorded. The adjoining selections were in the same rows on either side of K-S4. Data are presented showing the relative resistance of K-S4, with its adjoining and adjacent selections, on July 10, Aug. 16, and Sept. 15, 1928.

TABLE XXV. THE COMPARATIVE WILT RESISTANCE OF SELECTION K-S4 AND ITS ADJOINING AND ADJACENT SELECTIONS IN HEAVILY INFESTED SOIL, 1928.

Replication number	Date	Percentage resistance of K-S4	Percentage resistance of selections in			
			Adjacent row*	Adjacent row*	Adjoining section in the row*	Adjoining section in the row*
1	July 10	93	17		68	34
2	July 10	75	67	39	67	
3	July 10	60	37	56	45	
4	July 10	77	42	57	25	
1	Aug. 16	87	0		58	31
2	Aug. 16	75	34	25	34	
3	Aug. 16	60	0	44	34	
4	Aug. 16	74	33	57	25	
1	Sept. 15	55	0		8	0
2	Sept. 15	44	14	6	11	
3	Sept. 15	41	0	31	12	
4	Sept. 15	51	25	6	0	
Average	Sept. 15	47	8	9	6	0

*The selections which were planted adjacent to or adjoining K-S4 in the field, were some of the open-pollinated selections listed in table XXIV, and were more resistant than the commercial variety Kleckley Sweet.

On July 10, it appeared that there was a marked difference in the relative resistance of the selections designated as K-S4 and K-2, K-4. Flowers on all the plants which appeared resistant were self-pollinated. Approximately 2,000 flowers were self-pollinated and 109 ripe melons were harvested as shown in table XXIV. Of this number, 41 or 37.6 percent were the result of artificial self-pollination. The relative wilt resistance of selections K-S4 and K-15 in 1928 is shown in fig. 12.

Selections also were made at Fruitland on Sept. 16 and again on Oct. 3, 1927, in a 5-acre field from the Kleckley Sweet variety. Wilt had been severe in this field during July and August and by Sept. 16, the stand of disease-free plants had been reduced to about 150. Melons were selected from 25 plants which appeared resistant on Sept. 16. Again on Oct. 3, when there were only about 75 living plants in this field, 12 melons were picked from resistant plants. This seed was not the result of self-pollination. It was used to determine whether or not selection, unaccompanied by self-pollination, would prove advantageous in the isolation of resistant strains from susceptible varieties.

Selections were made Sept. 16 and Oct. 3 to determine whether or not there might be a positive correlation between the time at which progeny selections were made and their relative resistance. These selections were designated as KA2, KA3, KA6, KA7, KA11, KA16, KA18, KA19, KA29, KA10, KA26, KA21, KA27, KA28, KA31, KA35, KA36 and KA37.

Fig. 12. Relative resistance of selection K-S4 (Pride of Muscatine) on severely infested soil at Conesville in July, 1928. Row on left, selection K-15, 100 percent wilted. Middle row K-S4, 47 percent wilted.

Seed of these selections was planted in 1928 in 5-rod rows, 7 feet apart with 20 hills per 5-rod row, at the rate of 6 to 8 seeds per hill. Record was made of the initial stand and of the rate of wilting during the growing season with the results appearing in table XXVI.

The data in table XXVI indicate that selection (without self-pollination) within a commercial susceptible variety may be used to isolate resistant strains. Consideration should be given the fact that these selections were grown in the same field in which, in 1926 and 1927, Kleckley Sweet and 41 other commercial varieties were 99 percent susceptible. Further evidence that the soil in this field was heavily infested in 1928 is that only 55 melons matured from 2,243 original plants.

Many of these selections were as susceptible as the Kleckley Sweet variety. A few were less susceptible but only three, namely KA2, KA19 and KA31, appeared to be resistant. This was particularly true of KA2, which was 47 and 21 percent resistant, respectively, on Aug. 16 and Sept. 15, 1928. This selection produced 17 mature melons on resistant vines, while KA26 with a greater initial stand produced no mature melons. KA19 was 26 percent resistant on Aug. 16 and 19 percent on Sept. 15,

while on Aug. 16 KA10 was only 4 percent resistant and on Sept. 15 was 100 percent susceptible.

During the early part of the growing season of 1928, many of these selections appeared much more resistant than Kleckley Sweet, but as the season advanced only the three designated as KA2, KA19 and KA31 maintained this appearance. As is indicated in table XXVI, nine melons which resulted from artificial self-pollination matured on wilt resistant vines.

TABLE XXVI. RELATIVE RESISTANCE TO WILT OF SOME OPEN-POLLINATED SELECTIONS OF THE VARIETY KLECKLEY SWEET GROWN ON INFESTED SOIL AT CONESVILLE IN 1928.

Selection	Number of replications	Initial stand June 1	Percentage wilt									Yield	
			June 18	June 25	June 29	July 5	July 10	July 16	Aug. 1	Aug. 16	Sept 15	No. of ripe melons produced	No. of successful self-pollinations on resistant plants
KA2	16	216	0	15	22	34	35	48	48	53	79	17	3
KA3	11	170	1	16	29	36	37	49	64	88	94	2	0
KA6	13	159	1	21	27	44	51	54	61	74	90	3	0
KA7	15	172	1	22	36	48	56	65	68	79	92	3	1
KA11	10	147	1	9	17	28	33	43	61	74	91	3	0
KA16	12	179	1	21	31	43	44	53	58	69	89	4	0
KA18	4	47	1	25	27	47	47	49	69	91	94	2	1
KA19	7	127	0	29	35	41	46	47	59	74	81	7	1
KA29	3	36	0	59	61	72	72	84	88	94	100	0	0
KA10	7	105	1	18	31	44	46	49	81	96	100	0	0
KA21	7	79	4	8	36	55	61	67	71	84	96	1	0
KA26	9	264	3	48	53	68	70	75	79	91	100	0	0
KA27	11	223	7	38	49	62	69	79	83	88	100	0	0
KA28	10	171	2	38	44	63	65	71	76	89	97	1	0
KA31	6	73	8	41	48	57	61	63	63	70	83	5	1
KA35	7	102	3	38	52	69	73	81	81	81	86	5	1
KA36	8	136	7	42	52	66	70	71	79	84	93	2	1
KA37	4	47	4	36	37	39	46	49	63	81	100	0	0
Totals		2243										55	9
Kleckley Sweet (check)	6	241	18	44	51	63	75	89	96	98	99	1	0

TRIALS WITH THE TOM WATSON VARIETY

In addition to selections from the Kleckley Sweet variety, similar selections were made from the Tom Watson variety in 1927. Seed of this variety was planted in infested soil, flowers on resistant plants self-pollinated, and selections made as described in the case of the Kleckley Sweet variety. Three self-pollinated melons designated as MW-S1, MW-S2 and MW-S3 were secured. Seed was secured also from 15 open-pollinated melons and planted in two infested fields in 1928. The relative resistance of these selections in 1928 is shown in table XXVII, and indicates that selections from the commercial susceptible variety, Tom Watson, seemed to possess some resistance to wilt. This was true of selections designated as MW-13, MW-4 and

TABLE XXVII. RELATIVE WILT RESISTANCE OF SOME SELECTIONS FROM THE VARIETY TOM WATSON, BOTH SELF-POLLINATED AND OPEN-POLLINATED IN 1927, GROWN IN INFESTED SOIL AT CONESVILLE IN 1928.

Selection	Number of replications	Initial stand June 1	Percentage wilt									Yield	
			June 18	June 25	June 29	July 5	July 10	July 16	Aug. 1	Aug. 16	Sept 15	No. of ripe melons produced	No. of successful self-pollinations on resistant plants
MW-S1	1	37	0	8	16	27	30	46	91	91	91	1	1
MW-S2	1	16	0	0	0	19	19	25	93	98	98	0	0
MW-1	2	98	0	8	11	30	35	50	78	92	93	0	0
MW-3	2	95	0	9	14	28	36	45	78	81	91	0	0
MW-4	2	34	0	15	15	17	20	26	56	64	81	3	0
MW-2	2	104	0	3	10	12	22	36	80	83	86	0	0
MW-6	2	85	0	10	11	18	23	39	71	89	89	2	2
MW-7	1	45	0	31	39	46	57	66	100	100	100	0	0
MW-8	1	54	0	28	33	44	53	59	96	100	100	0	0
MW-9	1	39	0	29	38	43	43	46	100	100	100	0	0
MW-10	1	39	0	10	13	36	46	62	76	83	95	1	1
MW-11	1	36	0	6	16	25	27	42	97	100	100	0	0
MW-12	1	52	0	13	27	34	34	46	100	100	100	0	0
MW-13	1	27	6	8	8	11	11	18	43	59	78	3	0
MW-14	1	42	0	30	43	64	64	76	98	100	100	0	0
MW-15	1	39	0	23	36	46	54	59	100	100	100	0	0
Total		841										10	4
Tom Watson (check)		216	3	26	51	64	76	84	96	98	98	0	0

MW-2. Unfortunately, no self-pollinated melons were secured from selections MW-13 or MW-4, and no melons ripened in the case of MW-2. As is shown in table XXVII, however, two self-pollinated melons were secured from selection MW-6, and one each from selections MW-S1 and MW-10.

MASS SELECTIONS MADE IN 1928

The results thus secured in 1927 by selection of selfed and open-pollinated melons led to more extensive selecting in 1928. This work was undertaken in four fields. Field no. 1 (2 acres) had been planted with seed of the Kleckley Sweet variety which was the result of both self and open-pollination in 1927. The relative resistance of these selections has been indicated in table XXIV and previously summarized (27). Selections of both self and open-pollinated melons were made from resistant vines during September, 1928.

Field no. 2 (about 3 acres) had been planted with seed of the Kleckley Sweet variety. On Aug. 1, approximately 75 percent of the plants were infected. On Aug. 15, 89 disease-free plants were chosen. On Sept. 8, 64 of these 89 plants showed wilt infection. On Sept. 20, selections were made from 22 plants which still appeared resistant. The relative resistance of some of these selections to seedling wilt in the greenhouse is indicated in table XXXI (see p. 182).

Field no. 3 (about 1½ acres of wilt-sick soil) had been planted with seed of the Kleckley Sweet variety. Wilt did not appear to be serious in this field in the early part of the season, and on Sept. 20 only 40 percent of wilt was noted. The wilt situation suggested this field as a very desirable place to make selections, and 14 were made to determine: (a) whether such selections would prove resistant in future generations; or (b) whether this particular strain of Kleckley Sweet was naturally resistant to the disease.

Field no. 4 (15 acres) had been planted with seed of the Kleckley Sweet variety. The stand was normal and there were about 15,000 plants in the field. This field produced its last crop of watermelons in 1920, a limited amount of wilt having appeared that year. On July 5, 8 percent of the plants had wilted. On July 25 and Aug. 10, respectively, 22 and 58 percent of the plants had wilted, indicating that heavy loss probably would be incurred before the melons would ripen. On Sept. 1, the fourth count was made, and it was found that 82 percent had wilted. Accordingly, the plants in 286 hills which appeared resistant on Sept. 1, were marked. By Sept. 10 it was found that many of these plants had wilted and on Sept. 22, when the selections were made, only 31 melons were secured from the plants showing no wilt. The crop was a failure. The relative resistance of these selections to seedling wilt is shown by the data in table XXX (p. 180).

HYBRIDIZATION

It is well established that most of the inedible varieties of *Citrullus vulgaris* are relatively resistant to wilt. Having determined that the Stock Citron variety was wilt-resistant, Orton (19) crossed this variety on the commercial wilt-susceptible variety Eden. After 8 years of selection, he developed the edible wilt-resistant variety Conqueror. His work indicated that it was not difficult to secure resistance in this way, but that it was more difficult to fix the type and quality of the melons. Since Orton had been successful in developing wilt-resistant strains by hybridization, this method was undertaken by the writers in 1926.

VARIETIES CHOSEN AS STOCKS

Seven edible, susceptible commercial varieties were chosen as stocks, namely: Kleckley Sweet, Tom Watson, Halbert Honey, Thurmond Gray, Stone Mountain, Dixie Belle and Excel. The first two mentioned varieties are most widely used in Iowa.

The inedible resistant varieties chosen for hybridization with these susceptible varieties were Majorta, Mammoth White, Stock Citron, Preserving Citron, White Seeded and Kafir. The Conqueror variety was also used in crosses with edible susceptible varieties, because at the beginning of this work Conqueror was assumed to be wilt-resistant. Trials in 1926 and 1927, however, indicated that the Conqueror variety was only slightly more resistant than Kleckley Sweet.

ARTIFICIAL CROSSES OF THE VARIETY CONQUEROR ON FOUR COMMERCIAL VARIETIES

Crosses of Conqueror on the Kleckley Sweet and Tom Watson varieties were made at Conesville in 1926. The F_1 seed of these crosses was planted in the greenhouse in November, 1926, and self-pollinated melons ripened in May, 1927.

Although Orton (18) stated that F_1 plants resulting from crosses of the Eden variety with Stock Citron must be grown on wilt-free soil, indicating that resistance to wilt was inherited as a recessive character, it was thought best to determine this point for each F_1 generation. Accordingly, the two lots of F_1[5] seed derived from crossing Conqueror on the varieties Kleckley Sweet, Excel, Halbert Honey and Tom Watson were planted in infested soil in the field in 1926. By July 15 the F_1 plants were wilting as rapidly as those of the varieties Kleckley Sweet and Tom Watson. At the end of the growing season, 99.8 percent of the plants of the F_1 generation had died, indicating that resistance was inherited as a recessive character in the varieties used. The F_1 plants of crosses of the Conqueror variety with Kleckley Sweet and Tom Watson were grown also in disease-free soil and the flowers were self-pollinated in order to secure F_2 seed for trial on infested soil. The four lots of F_2 seed produced in the greenhouse during the winter of 1925-26 were planted in two infested fields in 1926, and efforts made to self-pollinate so as to secure at least one self-pollinated melon on each resistant plant. A few plants appeared resistant in 1926 and self-fertilized seed was secured for further trial in 1927. The resistance of the F_2 was low in 1927, indicating that the Conqueror variety, which had been used as the resistant parent in these crosses, was not entirely resistant. This was found to be true when this variety was planted in infested soil in 1926, 1927 and 1928. By Sept. 20, during these 3 years, there was no appreciable difference in the relative wilt resistance of the varie-

[5]Crosses of Conqueror on the varieties Kleckley Sweet and Tom Watson had been made in 1925 at Lacey, Iowa, on the Frank Everett farm, and the F_1 seed was planted in the greenhouse in November of the same year. Dr. O. H. Elmer secured four self-pollinated melons which ripened in May, 1926. This seed grown in the greenhouse was turned to the authors by Drs. S. M. Dietz and O. H. Elmer, to whom the authors are profoundly grateful.

ties Conqueror and Kleckley Sweet. Earlier in the season Conqueror appeared resistant, but during the hot weather which prevailed in July and August the plants of this variety wilted rapidly. Thus the F_2 of crosses of Conqueror on Kleckley Sweet could not be expected to be markedly resistant.

In 1926 and again in 1927, however, several F_2 and F_3 plants resulting from crosses of the Conqueror on Kleckley Sweet, Tom Watson and Excel, proved to be resistant when grown in severely infested soil at Conesville and Fruitland. Self-fertilized seed was secured from such plants for further trial. In three infested fields in 1928, five hybrids of Conqueror on commercial varieties indicated enough resistance to justify further trials. The history and development of these five strains follow:

PARENTAGE OF FIVE HYBRIDS

(A) Hybrid 43. Hybrid 43 resulted from a cross of the Conqueror variety ♂ x the Excel variety ♀ in 1926. The F_1 was grown and selfed in disease-free soil in 1927, while the F_2 was grown and selfed on heavily infested soil at Conesville and Fruitland in 1928 and proved moderately resistant. Those plants which lived produced melons of fairly uniform type and of excellent quality. The melons were more blocky than those of the Excel variety and with or without a faint stripe.

(B) Hybrid 30. Hybrid 30 resulted from a cross made by Drs. S. M. Dietz and O. H. Elmer at Lacey, Iowa, in 1925, of the Conqueror variety ♂ x the Kleckley Sweet variety ♀. The F_1 was grown and selfed in disease-free soil in the greenhouse at Ames during the winter of 1925-26. The F_2 was grown and selfed on infested soil at Conesville in 1926 and proved slightly resistant. Seed was secured from two selfed melons and planted in three infested fields in 1927. Again the resistance was quite low, but a sufficient number of selfed melons matured on resistant vines to justify more extensive trial in 1928. Seed from five such melons was planted in three infested fields at Conesville in 1928. The average resistance was 46 percent, while the Kleckley Sweet variety was 98 percent susceptible. The type of the melons produced in 1928 was not uniform, the shape varying from round to oblong and the color from dark green to striped. The flesh quality was inferior to that of hybrid 43.

(C) Hybrid 33. Hybrid 33 resulted from a cross made in 1926 of Conqueror ♂ x Halbert Honey ♀. The F_1 was grown and selfed in disease-free soil in the greenhouse at Ames during the winter of 1926-27. The shape of the F_1 melons was intermediate between the stocks, with skin color resembling that of the Halbert Honey. The flesh quality was satisfactory. The F_2 was grown and selfed in three infested fields at Conesville in 1927 where the resistance was only 10 percent, while Halbert

Honey was 100 percent susceptible. The shape of the F_2 melons varied from round to oblong; size, from small (10 lbs.) to medium (25 lbs.); color, from dark green to striped; with satisfactory flesh quality. Only one selfed melon was secured from a resistant plant in 1927, and seed from this melon was planted in two infested fields in 1928. The F_3 seed produced plants which were 59 percent resistant while the Halbert Honey variety was 100 percent susceptible in 1928. The type of the melons resembled that of Conqueror, but there was a tendency toward the oblong shape of the fruits of Halbert Honey. Few of the melons were striped, none as definitely marked as the Conqueror, mostly being dark green, resembling Halbert Honey in skin color. The quality was not exceptionally good.

(D) Hybrid 90. Hybrid 90 resulted from a cross made in 1926 of the Conqueror variety ♂ x the Kleckley Sweet variety ♀. The F_1 was grown and selfed in disease-free soil in the greenhouse at Ames during the winter of 1926-27. The F_1 melons resembled those of Conqueror in shape, with color resembling that of Kleckley Sweet. The F_2 was grown and selfed in three infested fields at Conesville in 1927 where it was slightly resistant; 8 percent of the plants matured ripe melons while the Kleckley Sweet variety was 99 percent susceptible. Those melons which ripened on resistant vines resembled Conqueror in shape, but had the dark green skin color characteristic of Kleckley Sweet. The flesh quality was more desirable than that of Conqueror. One selfed melon ripened on a resistant vine in 1927. The F_3 was grown and selfed in one infested field in 1928 where it was about 35 percent resistant, while the Kleckley Sweet was 100 percent susceptible. The type of the melons produced by resistant plants appeared well fixed, being round or nearly so, with skin color resembling that of Kleckley Sweet. The quality of the flesh was satisfactory.

(E) Hybrid 137. Hybrid 137 resulted from a cross made in 1926 of the Conqueror variety ♂ x the Kleckley Sweet variety ♂. The F_1 was grown and selfed in disease-free soil in the greenhouse at Ames during the winter of 1926-27. The F_1 melons were not uniform, but rather variable in quality, shape and color. In view of the fact that all other F_1 melons resulting from crosses of Conqueror ♂ x Kleckley Sweet ♀ were strikingly uniform in shape, color and quality, it was evident that contaminated pollen had been used in making the original cross. This was further evident when it was found that certain citron characters appeared in the melons in subsequent generations. The F_2 was grown and selfed in three infested fields in 1927 where the resistance was extremely variable, indicating again that some error had been made either in pollination or in handling the seed. Since the resistance of this hybrid was 60 percent in the F_2 in

1927, seed was saved from several selfed melons for further trial on infested soil. The F_3 was grown and selfed in three infested fields in 1928. The citron characteristics were absent in 1928, indicating that probably they had been eliminated during self-pollination and selection in 1927. The type of the melons produced on resistant vines in the F_3 in 1928 appeared to be well fixed. The majority of the melons were oblong, resembling the melons of Kleckley Sweet in shape. A faint stripe was usually evident on the skin. The resistance of the F_3 in 1928 was 55 percent.

Thus, the F_3 of five hybrids resulting from crosses of Conqueror ♂ x the commercial varieties Kleckley Sweet ♀, Halbert Honey and Excel, were resistant in 1928. During 1925 and 1926, 347 crosses were made between Conqueror and 7 commercial varieties, from which 63 hybrids were obtained. Only five of these have proven sufficiently resistant in the F_3 to justify further trial. The resistance of Conqueror is obscured during the hot weather which prevails in Iowa from late July through August. The probability of producing resistant varieties using Conqueror as the resistant parent is not great. It appears, however, from the results secured with such hybrids in 1928, that a relatively low percentage of the hybrids thus obtained are resistant in the F_3. Whether this relative resistance will be maintained in succeeding generations is as yet unknown, but as is shown in table XXX, the F_4 of hybrid 43, when indexed in infested soil in the greenhouse in 1928, appeared to be resistant to seedling wilt. The type of fruits produced in the F_2 of the cross Conqueror ♂ x Kleckley Sweet ♀ is shown in fig. 7.

CHANCE HYBRIDS OF THE VARIETY CONQUEROR ON COMMERCIAL VARIETIES

(A) (Iowa Belle) Q21[6]. This selection was originally made by Drs. O. H. Elmer and S. M. Dietz at Lacey, Iowa, in 1925, from a plant of the Conqueror variety. This plant was subject to pollination from plants of other varieties, particularly the variety Kleckley Sweet. The selection was tested in 1926 on lightly infested soil and appeared moderately resistant. The type and color of the fruit were exceedingly variable, and the melons appeared both in shape and color, to have been the F_1 of a cross of the Conqueror variety ♀ x the Kleckley Sweet variety ♂. The quality was satisfactory. Selfed seed was secured from two melons and open-pollinated seed from the same number. These four selections of seed, designated as Q21-S1, Q21-S2, Q21-3 and Q21-4, were planted in three heavily infested fields in 1927. Q21-S1 and Q21-S2 were completely susceptible. Q21-4 was slight-

[6]Described as Iowa Belle. Iowa Agr. Exp. Sta., Cir. 125. 1931.

ly resistant, while Q21-3 was 42 percent resistant at Fruitland. Seed of Q21-3 was secured from one open-pollinated melon and designated as Q-21-3-2. This seed was planted in two heavily infested fields at Conesville in 1928, and on Sept. 16 the progeny were 68 percent resistant and of remarkably uniform type. The only marked variation was that of size. The shape, color and quality were uniform. The melons were slightly oblong, of deep blue-green skin color, with faint short stripes. The remarkable uniformity and outstanding resistance of this chance hybrid no. Q21-3-2, justified extensive trial.

(B) (Iowa King) Q23[7]. The original selection was made at Lacey, Iowa, in 1925, by Drs. Elmer and Dietz from a plant of the Conqueror variety. The plant was subject to cross-pollination from other varieties. This selection was tested on infested soil at Conesville in 1926 and appeared moderately resistant. Three selfed melons were secured. These resembled Kleckley Sweet in size, shape and quality, but bore stripes characteristic of the Conqueror. They were designated as Q23-S1, Q23-S2 and Q23-S4. Seed from these melons was planted in three infested fields in 1927, and the progeny were found to be 11, 22 and 41 percent resistant. The shape was practically fixed, being almost identical with that of Kleckley Sweet. All of the melons bore a distinct stripe characteristic of the Conqueror variety, and all were of good quality. Seed was selected from three self-pollinated melons of Q23-S4 designated as Q23-S4-S1, Q23-S4-S2, and Q23-S4-S3 and planted in three infested fields in 1928. Selection Q23-S4-S3 was 64 percent resistant in 1928, being the most resistant of the three. The melons of this hybrid were almost identical with Q23-S4, the shape and size characteristic of the Kleckley Sweet variety, with distinct striping characteristics of Conqueror.

Thus, it appears that wilt resistant strains have been isolated by progeny selection following exposure of plants of the Conqueror variety to pollen from other varieties. Two of the twenty selections of Conqueror were resistant and of uniform type and quality. It should be noted that although the original selections were made in a field from the Conqueror variety, the melons of the two resistant strains developed from these selections are not like Conqueror, but probably new strains resulting from natural crossing between Conqueror and other commercial varieties. The original selection of hybrid Q21 was made in 1925. Progeny selection, without any attempt being made to control the pollination in 1925, 1926, or 1927, has resulted in the isolation of a strain relatively resistant and of uniform type and quality. Efforts are being made to determine whether or not this variety is sterile when foreign pollen is used. This may

[7]Described as Iowa King. Iowa Agr. Exp. Sta., Cir. 125. 1931.

furnish an explanation of the remarkable uniformity of the melons of hybrid Q21.

Rosa (30) has shown that some varieties (Angeleno and Snowball) of *Citrullus vulgaris* bear polygamous flowers, while most varieties usually bear imperfect flowers. Polygamous flowers have been observed on the varieties Majorta, Kafir, White Seeded, Mammoth White, Stock Citron, and Preserving Citron. Polygamy is a common characteristic of the inedible varieties of *Citrullus vulgaris* but is seldom found among the edible varieties. Q21 normally does not bear polygamous flowers.

CROSSES OF VARIETIES OF THE CITRON GROUP ON VARIETIES OF THE WATERMELON GROUP

An effort was made to develop wilt resistant varieties of watermelons by crosses of the variety Conqueror on a number of commercial susceptible varieties, and by crossing several inedible wilt resistant varieties (citron group) on commercial varieties of edible wilt susceptible watermelons. Orton (19) was able to develop the variety Conqueror by crossing inedible wilt resistant variety Stock Citron on the commercial susceptible variety Eden. It was realized at the beginning of these investigations in 1926 that by utilization of inedible varieties as resistant stocks the purification of the resulting hybrids from the standpoint of edibility would doubtless require many years. Moreover, it was realized that although the edible watermelon varieties were highly resistant, if not immune to mosaic, the red seeded citron was known to be susceptible. Thus, hybrids of varieties of the citron group on wilt susceptible watermelon varieties might prove susceptible to mosaic.

In view of Orton's success with the variety Stock Citron, however, as the resistant parent (19), it was decided to assemble all available citron varieties and to cross these on important edible, wilt susceptible varieties. These inedible varieties have been collected, tested for resistance to watermelon wilt, and many of them have been crossed on the varieties: Kleckley Sweet, Halbert Honey, Excel, Thurmond Gray and Tom Watson.

Inedible wilt resistant varieties used as stocks. The following inedible varieties have been used in crosses on edible wilt susceptible varieties: Kafir, White Seeded, Majorta, Mammoth White, Stock Citron, and Preserving Citron. The source and relative wilt resistance of these varieties are listed elsewhere in this bulletin. A brief description of the fruit of these inedible wilt resistant varieties follows:

(A) Kafir. Seed of this variety produced two distinct types of fruit: (a) oblong, with yellow skin, thick rind, white flesh,

and brown or tan seed coat; and (b) oblong, with dark green striped skin, white flesh and tan seed coat.

(B) White seeded. Seed of this variety also produced two distinctive types of fruit: (a) flat, with light green striped skin, pink to salmon colored flesh, thick rind and white seed coat; and (b) round, with dark green skin, salmon colored flesh and white seed coat. Three of the fruit types of the varieties Kafir and White Seeded are shown in fig. 8.

(C) Majorta. The fruit of this variety is oblong with dark green dappled skin, white to faintly pink flesh, large seeds and tan seed coat.

(D) Mammoth White. The fruit of this variety is flat, with yellow skin, white flesh and has pale purple seed coat.

(E) Stock Citron. The fruit of this variety is oblong with green or greenish-yellow skin, white flesh and green seed coat.

(F) Preserving Citron. The fruit of this variety is round. small, with striped green skin, hard white flesh and green seed coat.

Crosses were made in 1926 using the variety Preserving Citron as the resistant parent and the varieties Kleckley Sweet, Halbert Honey, Tom Watson, Excel and Thurmond Gray as the susceptible parents. F_1 plants were grown in infested and in non-infested soil at Conesville and Fruitland in 1927 and 1928, but it was found that these plants were highly susceptible to mosaic. In addition, the round type of the fruit of the variety Preserving Citron made it an undesirable stock. Further, it was found that both the White Seeded and the Kafir varieties were much more satisfactory than Preserving Citron as resistant stocks, because their type more nearly approached that of Kleckley Sweet; the F_2 plants were much less susceptible than the plants of Preserving Citron to mosaic, and, in addition, these two varieties were resistant to anthracnose caused by *Colletotrichum lagenarium* (Pass.) Ell. and Hals. Hence, the breeding of Preserving Citron hybrids was discontinued.

In 1928 seed of the variety Stock Citron was planted and crosses made of this variety on several commercial wilt susceptible varieties.

Seed of the varieties Mammoth White and Tsama was planted in 1928 and crosses made of the former on several commercial susceptible varieties. All attempts to cross the variety Tsama on commercial susceptible varieties failed. This was experienced whether the Tsama variety was used as the male or as the female parent. The variety Majorta was also crossed on commercial wilt susceptible varieties in 1928.

A cross of the inedible variety White Seeded ♂ x edible variety Halbert Honey ♀ was made in 1926. F_2 seed was secured from F_1 plants grown in the greenhouse during the winter of 1926-27.

The fruits produced by the F_1 plants were citron-like in shape, seed characters, flesh texture and quality, but the skin color resembled that of Halbert Honey. One selfed fruit was secured and seed was planted in infested soil at Conesville in 1927. The F_2 generation was 85 percent resistant. The shape of the fruit varied from round and flat to oblong; the skin color varied from dark green to dappling or mottling; the flesh quality varied from complete to slight inedibility; some fruits had hard, solid flesh; some soft and spongy, while others had flesh which resembled the texture of that of the variety Halbert Honey; the flesh color varied from white to yellow, pink and red, and some fruits were hollow in the center. Many fruits of desirable external characteristics were produced on resistant plants, but the flesh characteristics resembled the inedible resistant stock. Four selfed fruits were secured and the seed was designated as 156-S2-S, 156-S2-S1, 156-S2-S2, and 156-S2-S3. The fruit of 156-S2-S was slightly oblong with a hollow center and coarse stringy pink flesh. The skin color resembled that of the variety Halbert Honey. The fruit of 156-S2-S1 was also slightly oblong with skin color characteristic of Halbert Honey. The flesh was pink and yellow in spots, seeds being small and seed coat brown. The fruit of 156-S2-S2 was also slightly oblong resembling Halbert Honey both in shape and skin color. The flesh was yellow and soft, inedible, and the seed coat was brown. The fruit of 156-S2-S3 was typical of Halbert Honey externally, but the seed coat was brown and the pink flesh was streaked and spotted with yellow.

A brief summary of the type and quality of the fruits borne on resistant F_2 vines is presented in table XXVIII.

TABLE XXVIII. SUMMARY OF FRUIT CHARACTERS OF F_2 RESISTANT PLANTS OF HYBRID 156-S2. 1927.

Shape			Skin color		Flesh color			
No. round	No. slightly oblong	No. decidedly oblong	No. green	No. striped	No. red	No. pink	No. yellow	No. white
25	24	35	50	34	3	14	65	2

Seed from selfed F_2 fruits was planted in infested soil in two fields in 1928 and the average resistance of the four hybrids was 79 percent. The resistance of these hybrids and the flesh color of melons from resistant plants were variable. Data on these two factors are presented in table XXIX. It is shown that resistance varied from 63 to 91 percent. Hybrid 156-S2-S produced 19 melons on resistant plants, 2 with red, 13 with yellow, and 4

with white flesh. Hybrid 156-S2-S1 produced 30 melons on resistant plants, 12 with red, 15 with yellow and 3 with white flesh. All of the melons produced on resistant plants of hybrid 156-S2-S2 had yellow flesh. Hybrid 156-S2-S3 produced 52 melons on resistant plants, 23 with red and 29 with yellow flesh. Thus, hybrids 156-S2-S1 and 156-S2-S3 produced a greater percentage of red-fleshed melons than did the other two hybrids in the trial. The quality of the red flesh of hybrids 156-S2-S1 and 156-S2-S3 was low from the standpoint of edibility. Future breeding may serve to isolate strains which will produce melons of higher quality.

TABLE XXIX. QUALITY AND RESISTANCE IN THE F_3 GENERATION RESULTING FROM A CROSS OF THE VARIETY WHITE SEEDED ON THE VARIETY HALBERT HONEY. 1928.

Breeding No.	Percentage resistance	Flesh color			
		No. red	No. yellow	No. white	Total
156-S2-S	63	2	13	4	19
156-S2-S1	79	12	15	3	30
156-S2-S2	85	0	45	0	45
156-S2-S3	91	23	29	0	52
Totals	79	37	102	7	146

It required eight years for Orton (19) to purify and improve the variety Conqueror so that it could be distributed to growers and seedsmen. It now appears that at least 6 years and possibly a longer time will be required to purify hybrid 156. F_3 plants of this hybrid are relatively resistant in infested soil, but the flesh quality as well as type of the melons is not satisfactorily fixed.

METHODS OF MEASURING THE RELATIVE WILT RESISTANCE OF VARIETIES, SELECTIONS AND HYBRIDS IN THE GREENHOUSE

During the progress of these investigations, it became essential to develop greenhouse technique for determining relative wilt resistance. It was evident that with the development and utilization of such technique the relative wilt resistance of varieties, selections and hybrids could be determined in the seedling stage.

Nearly all of the preliminary trials conducted during the winter of 1926-27 proved unsatisfactory. The reasons became obvious after a careful study had been made of infection phenomena, the relation of the degree of soil infestation to infection, the relation of soil temperature to infection, seed disinfection, effects of transplanting and the symptoms produced.

After these phenomena had been investigated it was possible to devise a method of indexing the relative wilt resistance of seedlings of varieties, selections and hybrids. It was found that inoculum was effective when mixed with steamed soil at the rate of 2:700 grams.

At the end of the growing season of 1928, several hundred lots of seed were available for indexing. These included mass selections, varieties, and hybrids in the F_1, F_2, F_3 and F_4 generations. The soil used was composed of a mixture of 2 parts greenhouse bench soil and 1 of river sand, steamed 3 times at 25 pounds pressure for 3 hours on alternate days. One-half pint of this soil was placed in a 4-inch greenhouse pot and 2 grams of finely powdered inoculum of *Fusarium niveum* were applied in a thin layer at the soil surface. The pot was then filled to within 1 inch of the top. Twenty-five surface disinfected seeds were then planted and covered with steamed soil. The soil was watered and the pots placed on a greenhouse bench where the soil temperature varied from 21-29° C. As soon as seedling wilt appeared, daily records were made of the rate of wilting. Results of such trials are presented in tables XXX and XXXI.

The data in table XXX indicate that the relative wilt-resistance of selections, hybrids and varieties may be determined in the greenhouse. Such determinations require accurate soil dosage with a small amount of inoculum. It will be noted that after 34 days the susceptibility of the varieties Kleckley Sweet, Tom Watson and Stock Citron, was 69, 67 and 17 percent, respectively, while after 40 days the susceptibility of these three varieties was 76, 89, and 35 percent, respectively. It will be noted that many selections and hybrids were as resistant as the variety Stock Citron after 34 days. Such was true of the following mass selections: B3, B7, and B15; and of the following hybrids: 43-S1-S2, 33-S1-S1-S1, 156-S2-S3-S1 and 156-S2-S3-S2. Attention should be called to the fact that many selections and hybrids were more resistant than the varieties Kleckley Sweet and Tom Watson.

Similar trials were conducted using additional hybrids and selections with the results which are presented in table XXXI.

The data in table XXXI further indicate that the method used gave a fairly accurate index of the relative resistance of the selections, varieties and hybrids used. The selections designated as H2, H3, H4, H5, H7, H8, H9, H10, H11, H12 and H13 appeared to vary slightly in their resistance after 40 days. The resistance of H8 was 47 percent and that of H2 only 12 percent. The "Japan 7" selections were the result of artificial self-pollination in 1928. This variety, as indicated elsewhere in this paper, was resistant in the field in 1928. "Japan 7-S1" appeared

TABLE XXX. INDEX OF WILT RESISTANCE OF CERTAIN HYBRIDS AND SELECTIONS IN THE GREENHOUSE. GROUP 1.

Breeding number	Generation (if hybrid)	History	Initial stand	Percentage of plants wilting							
				Days after planting							
				20	24	26	30	32	34	36	40
None		Kleckley Sweet (check)	117	4	15	17	47	53	69	72	76
None		Tom Watson (check)	112	14	27	33	55	61	67	78	89
None		Stock Citron (check)	40	0	2	2	2	7	17	22	35
None		Kleckley Sweet (non-infested soil)	50	0	0	0	0	0	0	0	0
None		Tom Watson (non-infested soil)	46	0	0	0	0	0	0	0	0
None		Stock Citron (non-infested soil)	50	0	0	0	0	0	0	0	0
43-S1-S1	3	Conqueror x Excel	50	4	18	24	54	58	64	68	78
43-S1-S2	3	Conqueror x Excel	41	0	7	7	12	14	19	24	36
43-S1-S3	3	Conqueror x Excel	48	8	21	34	51	55	57	59	71
43-S1-S4	3	Conqueror x Excel	47	4	54	62	81	86	90	90	90
43-S1-S5	3	Conqueror x Excel	49	24	30	30	60	66	78	78	87
33-S1-S1-S1	4	Conqueror x Halbert Honey	47	4	5	5	12	16	16	25	33
33-S1-S1-S2	4	Conqueror x Halbert Honey	49	4	22	30	52	60	65	67	71
33-S1-S1-S3	4	Conqueror x Halbert Honey	47	2	13	15	29	37	46	52	61
30-B-S1-S2	4	Conqueror x Kleckley Sweet	46	4	27	32	51	53	62	62	66
Q23-S4-S1-S1	4	Probably chance hybrid*	46	6	9	17	51	62	76	78	84
Q23-S1-S1-S1	4	Probably chance hybrid*	50	2	12	20	62	62	66	66	82
Q23-S1-S1-S2	4	Probably chance hybrid*	48	13	25	33	37	41	52	52	60
Q23-S1-S1-S10	4	Probably chance hybrid*	35	0	3	6	11	29	39	41	54
Q23-S1-S2-S1	4	Probably chance hybrid*	47	22	31	36	51	55	63	69	79
Q20-S4-4-S1	4	Probably chance hybrid	49	0	12	14	40	48	54	56	61
156-S2-S2-S3	4	White Seeded Citron* Halbert Honey	39	13	18	22	38	43	56	59	69
156-S2-S2-S4	4	White Seeded Citron x Halbert Honey	46	28	34	37	56	56	59	62	76
156-S2-S2-S5	4	Halbert Honey	46	13	30	30	48	48	53	62	71
156-S2-S2-S6	4	Halbert Honey	47	2	4	13	41	46	56	59	65
156-S2-S2-S7	4	Halbert Honey	49	0	6	10	32	38	46	51	57
156-S2-S3-S1	4	Halbert Honey	48	2	2	2	2	2	2	4	7
156-S2-S3-S2	4	Halbert Honey	46	2	18	21	48	50	59	62	71
156-S2-S3-S3	4	Halbert Honey	48	0	2	2	12	13	22	28	35

TABLE XXX. (Cont.) INDEX OF WILT RESISTANCE OF CERTAIN HYBRIDS AND SELECTIONS IN THE GREENHOUSE. GROUP 1.

Breeding number	Generation (if hybrid)	History	Initial stand	Percentage of plants wilting							
				Days after planting							
				20	24	26	30	32	34	36	40
B1		Selected from a resistant Kleckley Sweet vine in field no. 4, 1928**	24	4	25	33	52	71	75	75	89
B3		" " "	52	0	0	2	9	9	9	13	15
B4		" " "	50	14	30	44	64	70	72	78	80
B6		" " "	50	6	38	48	60	64	88	88	88
B7		" " "	48	2	4	4	12	12	24	26	32
B8		" " "	31	0	6	6	42	49	51	55	59
B9		" " "	50	4	12	22	40	46	48	52	68
B10		" " "	46	3	5	5	19	26	31	39	53
B11		" " "	45	13	31	31	57	62	64	71	78
B12		" " "	48	15	29	33	61	67	69	69	75
B14		" " "	50	0	8	12	32	32	42	48	52
B15		" " "	49	2	2	4	12	16	16	16	16
B16		" " "	50	12	20	20	49	58	68	68	76
B17		" " "	42	19	35	50	74	76	77	77	89
B19		" " "	49	14	30	30	52	56	63	63	71
B21		" " "	50	22	48	58	84	84	86	86	90
B22		" " "	43	12	16	17	33	33	39	40	46
B23		" " "	39	5	19	21	32	38	39	41	49
B24		" " "	42	15	40	49	76	80	81	82	85
B25		" " "	50	6	10	14	38	46	64	66	80
B26		" " "	49	12	21	32	51	60	68	69	74
B27		" " "	48	14	22	22	35	45	45	48	68
B28		" " "	47	17	21	21	52	63	66	66	71
B29		" " "	50	22	32	38	58	60	64	68	78
B31		" " "	31	6	16	19	36	45	55	64	71

*See page 174 for description of chance hybrid Q23.
**See page 169 for description of selections B1, B3, etc.

TABLE XXXI. INDEX OF RELATIVE WILT RESISTANCE IN THE GREENHOUSE OF CERTAIN ADDITIONAL HYBRIDS AND SELECTIONS. GROUP 2.

Breeding number	Generation (if hybrid)	History	Initial stand	Percentage of plants wilting							
				Days after planting							
				19	22	24	29	31	33	38	40
None		Kleckley Sweet (check)	50	16	24	48	74	74	89	94	94
None		Tom Watson (check)	46	18	31	53	81	81	81	91	91
None		Stock Citron	51	0	1	3	3	3	6	15	16
None		Kleckley Sweet (non-infested soil)	49	0	0	0	0	0	0	0	0
None		Tom Watson (non-infested soil)	50	0	0	0	0	0	0	0	0
None		Stock Citron (non-infested soil)	53	0	0	0	0	0	0	0	0
Q23-S4-S3-S2	4	Probably chance hybrid*	42	7	12	14	20	20	24	33	35
Q23-S4-S3-S3	4	Probably chance hybrid*	49	0	0	2	12	12	14	16	18
Q23-S4-S3-S4	4	Probably chance hybrid*	49	2	2	2	8	14	16	34	34
Q23-S4-S3-S5	4	Probably chance hybrid*	49	6	8	14	22	28	32	36	38
Q23-S4-S3-S6	4	Probably chance hybrid*	48	0	2	7	17	18	22	26	26
Q23-S4-S3-S7	4	Probably chance hybrid*	45	5	11	14	26	26	28	36	40
Q23-S4-S3-S8	4	Probably chance hybrid*	47	7	9	11	28	33	37	43	50
Q23-S4-S3-S9	4	Probably chance hybrid*	49	0	8	12	16	20	22	29	31
Q21-3-2-S3	4	Probably chance hybrid*	47	7	19	28	33	37	43	48	48
Q21-3-2-S4	4	Probably chance hybrid*	50	24	28	32	34	40	42	48	50
Q21-3-2-S5	4	Probably chance hybrid*	44	14	18	20	29	29	31	31	31
Q21-3-2-S6	4	Probably chance hybrid*	48	11	13	13	33	33	41	43	43
H1		Selected from a resistant Kleckley Sweet vine in field no. 2, 1928**	49	26	46	49	56	59	59	65	67
H2		" " "	50	18	26	44	62	64	72	88	88
H3		" " "	50	18	36	42	52	58	68	68	70
H4		" " "	49	16	26	36	58	63	65	79	79
H5		" " "	48	23	35	53	71	71	75	80	80
H7		" " "	48	7	15	19	53	65	75	84	86
H8		" " "	51	19	31	40	45	49	51	51	53
H9		" " "	50	18	28	48	56	60	68	72	74
H10		" " "	49	12	24	28	46	47	51	55	55
H11		" " "	45	9	9	27	40	43	48	51	55
H12		" " "	50	12	22	24	46	48	52	56	58
H13		" " "	50	16	34	46	62	62	62	66	68
Japan 7-S1		Foreign variety	39	0	0	0	5	7	10	10	10
Japan 7-S3		Foreign variety	38	0	0	3	6	13	13	19	23
Japan 7-S4		Foreign variety	45	2	2	8	14	14	14	24	24
Japan 7-S5		Foreign variety	46	0	5	7	18	18	24	29	29
Japan 7-S6		Foreign variety	45	0	0	5	14	16	19	24	24
Cone 1-S2-1-S1		Conqueror selection	48	0	0	2	7	11	11	23	23

*See pages 173 and 174 for a description of chance hybrids Q21 and Q23.
**See page 168 for a description of selections H1, H2, etc.

to be slightly more resistant than the Stock Citron variety after 40 days.

In this experiment (table XXXI) the varieties Kleckley Sweet and Tom Watson were, respectively, 94 and 91 percent susceptable after 40 days, while the susceptibility of Stock Citron at this time was only 16 percent. This relation more nearly approximates the relative resistance of these three varieties under field conditions than the data presented in table XXX.

Attention is directed to the difference in resistance of the selections in the series Q23-S4-S3-S2. The resistance of these selections after 40 days varied from 18 to 50 percent.

The relative response to wilt resistance of seedlings growing in infested soil in the greenhouse is shown in fig. 9, page 155, and in figs. 10 and 11 on page 156.

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